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ABSTRACT

Intended for use in a 1-year curriculum in an area vocational high school, this student manual for machine shop work with industrial metals contains 17 instructional units, each with a behavioral objective, related information, shop procedures, equipment and materials lists, and student worksheets. Developed by a regional group of teachers and supervisors and tested in four vocational schools, this text was prepared by the chairman of the drafting department at an area vocational high school. A course rationale, supplies list, a glossary, reference lists, and student achievement tests are included. Working diagrams and other visual aids illustrate the text. (AG)

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STRENGTH OF MATERIALS - MACHINISTS

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ED 072244

STRENGTH OF MATERIALS - MACHINISTS

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STRENGTH OF MATERIALS FOR MACHINISTS

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STRENGTH OF MATERIALS FOR MACHINISTS

INTRODUCTION

PURPOSE OF THE COURSE

A certain amount of machine shop work consists of the solution of physical problems beyond the everyday running of machines. These problems usually involve principles of strength of materials. The application of these principles may be simple or complex. The great majority of the complex ones are handled by the engineering department. The machinist may be called in to lend his knowledge when needed. It is essential, though, that a prospective machinist should be introduced to problems, typical methods of arriving at a solution, and acceptable standards of presenting this data.

To teach typical methods of working a problem in detail would be a difficult task and not necessary for the machinist. A simple outline that would be agreeable to a tradesman is a general one. This outline would follow a method of solution that would attempt to explain:

1. An understanding of the required problem.
2. The assembling of observed data.
3. The setting up of an objective which will let the machinist progress to the result.
4. The use of some means or method to check the result or results.

The problems which the machinist runs up against are of varying types and degrees of difficulty. In science, you solved problems that could be done by simple reasoning through previous experiences. In physics, more complex problems and experiments were undertaken to give you a background in physical principles. In Strength of Materials, you will experience problems and gain knowledge that will help you in your future work as a machinist.

In all cases, the machinist should never forget that not only is he solving for a result, but also for the record. In commercial practice the reports are filed for future reference, either by the machine shop or engineering departments. Make the records complete and easy to read to save time and money.

Because there is no excuse for a great difference in standards of performance, the student should learn the importance of doing a job properly the first time. To work a problem in a careless manner and then copy a careful, neat paper to present as the finished job, is a waste of time. Any careless habits you acquire as a student are likely to show up as work that cannot be accepted in the future.

By demanding a good quality of work in this course, we expect that good performance standards will be used, as well as the starting of satisfactory work habits.

The appearance of the work is one of the ways of showing how reliable it is.

MATERIALS AND SUPPLIES

The material needed to satisfy the requirements of the course follow:

A. Books
   1. This manual
   2. References and other materials suggested by the instructor.
   3. Any science or physics texts that you may find useful.
   4. Do not be limited by these references. There are others.

B. Paper
   1. Ruled white or plain white

C. Pencil with eraser
   1. Well-pointed for clear notes

D. Drawing equipment
   1. Compass
   2. Protractor
   3. Ruler

E. Folders
   1. One as a file for the unfinished work.
   2. Another as a file for the finished or graded work.

GENERAL FORM TO BE USED FOR WRITING OF JOB SHEETS

Shop ______________________ Student's Name ______________________

Class ______________________ Job Sheet No. ______________________

STRENGTH OF MATERIALS

Objective –

Sketch – (Omit if none needed)

Results –

Conclusions –

Answers to questions or problems – (if any are asked)

INDUSTRIAL MATERIALS

IRON AND STEEL

Strength of Materials – Machinists – Unit I Information Sheet No.1

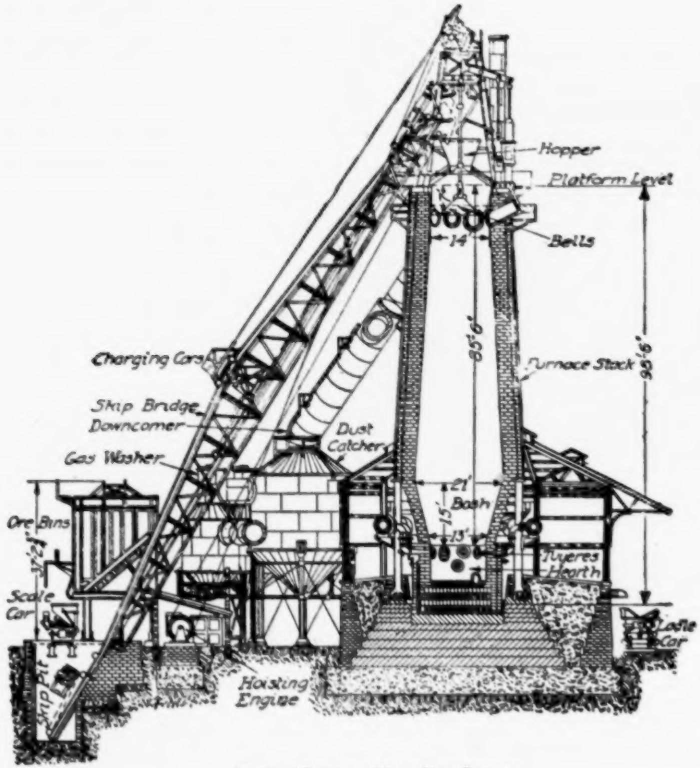
OBJECTIVE:

To learn what is meant by ferrous metals and how they are produced.

RELATED INFORMATION:

Up to recent times, the terms iron and steel have been loosely titled ferrous metals. A great advance in the science of metals has been the study of differences in iron and steel. The term iron and its chemical symbol (Fe, ferrous) is used when speaking of the element iron, while steel, a combination of iron and carbon in varying degrees, is spoken of as an alloy. A very soft steel used in the manufacture of wire has 0.05 to 0.12 percent carbon and a hard and strong steel used for tools and machinery has a range of 1.25 to 1.40 percent carbon. The question is, how do we obtain these metals?

First, the iron ore is mined. Three-fourths of the iron ore for use in the United States is secured in the Lake Superior region.


Hopper
Platform Level
Bells
14'
85'6"
93'6"
Charging Cars
Furnace Stack
Skip Bridge
Downcomer
Dust Catcher
Gas Washer
21'
Bosh
15'
13'
Ore Bins
37'21'
Tuyeres
Hearth
Scale Car
Ladle Car
Skip Pit
Hoisting Engine

Vertical Section of Iron Blast Furnace

FIG. 1 – BLAST FURNACE

Secondly, the ore is transported by boat or train to the nearest blast furnace (Fig. 1) where the iron is extracted and cast into pigs, or else taken to the steel-making furnaces in a molten state. The pigs are remelted for use in casting iron for machinery parts, or used cold in a puddling furnace to produce wrought iron. Wrought iron is valuable because of its ability to resist corrosion and fatigue failure. Also, since it is soft and ductile, wrought iron finds common usage in the manufacture of bolts, pipe, tubing, nails, etc.

The steel-making furnaces are the Bessemer Converter (Fig. 2) or the open-hearth furnace (Fig. 3). The Bessemer process produces an acid steel because of its refractory lining of silica. The steel produced is used mainly for wire, pipe, and screw stock.

The typical open-hearth produces a basic steel because of the lining of dolomite or magnesite and is used mainly for structural, spring, welding, boiler and sheet steels.

High grade tool steels and some alloy steels are made by the crucible process or by the electric-furnace process.

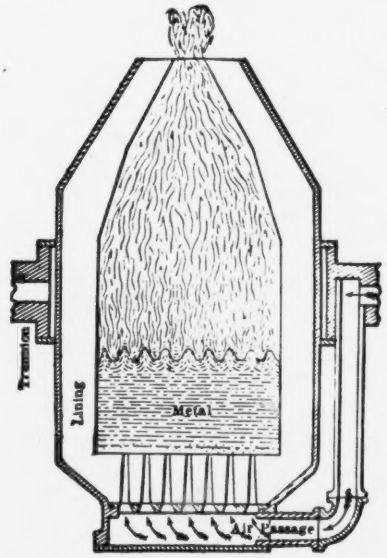


FIG. 2
CROSS-SECTION OF A
BESSEMER CONVERTER

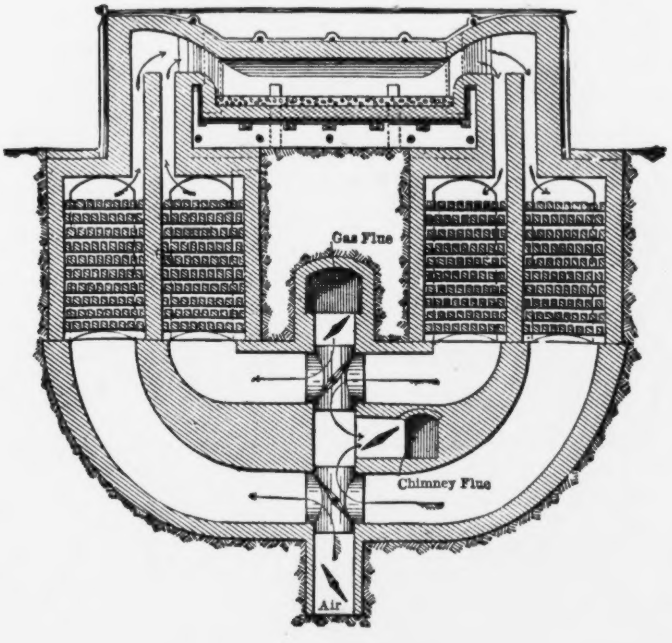


FIG. 3
CROSS-SECTION OF AN
OPEN-HEARTH FURNACE

IRON AND STEEL

SHOP ________________ NAME ________________________________

CLASS ________________ INFORMATION SHEET NO. 1-1

QUESTIONS

1. What is the chemical symbol for iron?

2. Name the steel-making furnaces.
   a.
   b.
   c.
   d.

3. What types of steel does each produce?
   a.
   b.
   c.
   d.

4. Give the percentage of carbon in a very soft steel.

5. Why is a blast furnace used?

6. Why is wrought iron valuable?

7. Give some uses of steel:
   a. With a high carbon content
      1.
      2.

   b. Produced by the open-hearth process
      1. 4.
      2. 5.
      3.

   c. Produced in the Bessemer converter
      1.
      2.
      3.

INDUSTRIAL MATERIALS

IRON AND STEEL

Strength of Materials – Machinist – Unit I Job Sheet No. 1

OBJECTIVE:

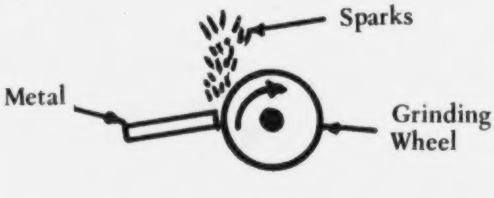
To learn how to test iron or steel.

WANTED:

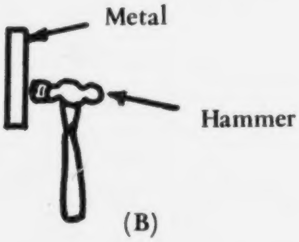
Methods of testing materials to see if they are iron or steel.

RELATED INFORMATION:

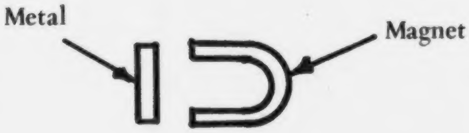
Many times in the course of replacing a part on a machine, the data relative to the material of the part is unknown. By remembering these several methods to test a part for its metallic content, you will save the company you are working for many hours of labor.



(A)



(B)



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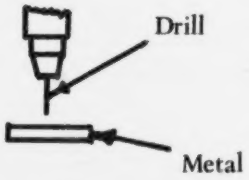


(D)

MATERIALS:

Pieces of cast iron, wrought iron, soft and hard steels, tool steel, grinding wheel, hammer, magnet and drill press.

PROCEDURE:

(These tests should be made in the machine shop. Writing of experiments will be completed in class.)

1. Take a sheet of paper to note the results of each step.

2. Take each metal and note sparks when testing as in Fig. A. Record what you observe.

3. Take each metal and see if it will resist or break from a blow of a hammer as shown in Fig. B. Do the metals have the same ring when struck with the hammer? Record your results.

4. Take each metal and see if the metal is attracted to the magnet. (See Fig. C.) Put on your paper the results of the test.

5. Take each metal and drill into it. (See Fig. D). Note the chip from drilling. Record your results. Keep chip samples for mounting on wood or cardboard.

IRON AND STEEL

SHOP ________________ NAME ___________________________________

CLASS ________________ JOB SHEET NO. 1

QUESTIONS

1. Which is more fragile with regard to shock, cast iron or steel? Explain.

2. Explain why the various metals give off different spark pictures.

3. Make simple sketches of various spark tests.

INDUSTRIAL MATERIALS

NON-FERROUS METALS

Strength of Materials – Machinists – Unit I   Information Sheet No. 2

OBJECTIVE:

To learn how non-ferrous metals are named and how they are produced.

RELATED INFORMATION:

You, living in a metal age, should get some idea of the size of the metal industry. Check the yearly production of all metals from their ores in an almanac or some other suitable reference to see these figures. You will find the value of these metals is great.

Since iron and its alloys account for around 90 percent of the tonnage of metals produced, it is placed in one group, while the remaining metals are classed as non-ferrous. Some of the more important ones are copper, lead, zinc, tin, nickel, aluminum, magnesium and cadmium.

The great majority of the non-ferrous metals can be used in the pure state or as the principal part of an alloy. Some are used as minor parts of alloys, while mixtures of the non-ferrous metals result in extremely important alloys.

Each of the metals has its own production methods, which will be briefly sketched.

Most of the aluminum exists in the outer layer of the earth. It is mined as a commercial ore and refined into aluminum. The larger quantity of aluminum is used in the manufacture of furniture, airplanes, railroad and trolley cars, automobiles, electric cables and bus bars, conduits, rivets, kitchen utensils, tubes of pastes, siding and roofing, jar caps, etc.

Copper, one of the most widely distributed metals, is mined for smelting in furnaces. Because of the bad effect of impurities on the electrical conductivity of copper, the metal must go through a refining process. The largest proportion of copper produced is used in the electrical industry, while the remainder finds uses in copper alloys or other purposes where corrosion resistance with some strength and easy shaping is essential.

Lead is mined in nearly every country. The deposits of ore are found to be a mixture of lead and zinc in varying proportions. In practice, the reducing of lead ore is complex. Floatation, blast-furnace smelting, leaching and refining are steps in producing commercial lead. Lead finds great use in chemical laboratories and plants as a lining because of its resistance to acids. Other applications are electric cable sheaths, gutters, storage battery plates, and in the manufacture of paint products.

Zinc is extracted from ores by the electrolytic method. After refining, the zinc finds great use in galvanizing and some use as an alloy in the making of brass.

Tin is the only major metal of industrial use that is not found in great quantities in the North American continent. It is mined chiefly in Malaysia, Indonesia, and Bolivia. The ore has to be delivered to the smelting furnace in as pure a concentrate as possible. After smelting, tin has to be refined for tin plating, solders, babbitt, and brass and bronze alloys. Approximately one-third of the tin used in the United States consists of reclaimed tin. This system of recovering otherwise wasted tin for use in oxides, salts, and alloys, releases new tin for other purposes.

Cadmium, obtained commercially as a by-product in the processing of zinc and sometimes lead, is probably the first metal that was not discovered in ore. Cadmium is being used as a substitute for tin in solder and in anti-friction alloys for bearings.

Magnesium is found on the earth's crust in great deposits which yield a good amount for production. The metallic magnesium is prepared by refining. It is marketed in many forms for ease in transporting to factories where it may be used to form sheets, wire, rods, tubes, or is alloyed with most metals.

In the core of the earth, plenty of nickel it is believed can be found. Canada and Wales are chief producers of nickel ore for smelting and bessemerizing. Nickel has good use in Monel metal, which resists most acids. It is also used in other important ferrous and non-ferrous alloys as a protective coating on iron or brass.

NON-FERROUS METALS

SHOP________________ NAME ________________________________

CLASS ________________ INFORMATION SHEET NO. 1-2

QUESTIONS

1. Name eight non-ferrous metals.

a.	e.
b.	f.
c.	g.
d.	h.

2. Give a use for each of the non-ferrous metals you listed.

a.	e.
b.	f.
c.	g.
d.	h.

3. What is the percent of tonnage of production of non-ferrous metals when compared with all metals produced?

4. Which of the non-ferrous metals do you think is most important to us as a nation? Why?

INDUSTRIAL MATERIALS

NON-FERROUS METALS

Strength of Materials – Machinists – Unit I Job Sheet No. 2

OBJECTIVE:

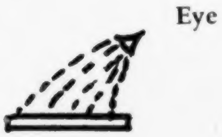
To learn some tests for recognizing non-ferrous metals.

WANTED:

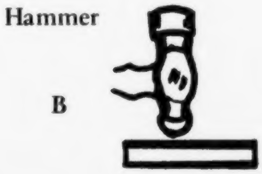
Examples of tests of non-ferrous metals.

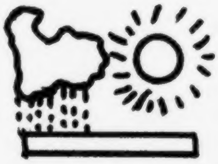
SKETCH:

A



B





C

MATERIALS:

Samples of aluminum, copper, lead, and tin-and zinc-coated materials, hammer.

PROCEDURE:

1. Observe the color of the various metals as shown in Fig. A. Record your observations.
2. Strike each metal a blow with the hammer as shown in Fig. B. Record on your paper how soft or hard the metals are. Do any of them chip?
3. Expose the various materials to the weather, as shown in Fig. C, during a rainy and sunny period for one week. (Add water if no rainfall occurs for a couple of days). What happens to the various metals?

INDUSTRIAL MATERIALS

ABRASIVES

Strength of Materials – Machinists – Unit I Information Sheet No. 3

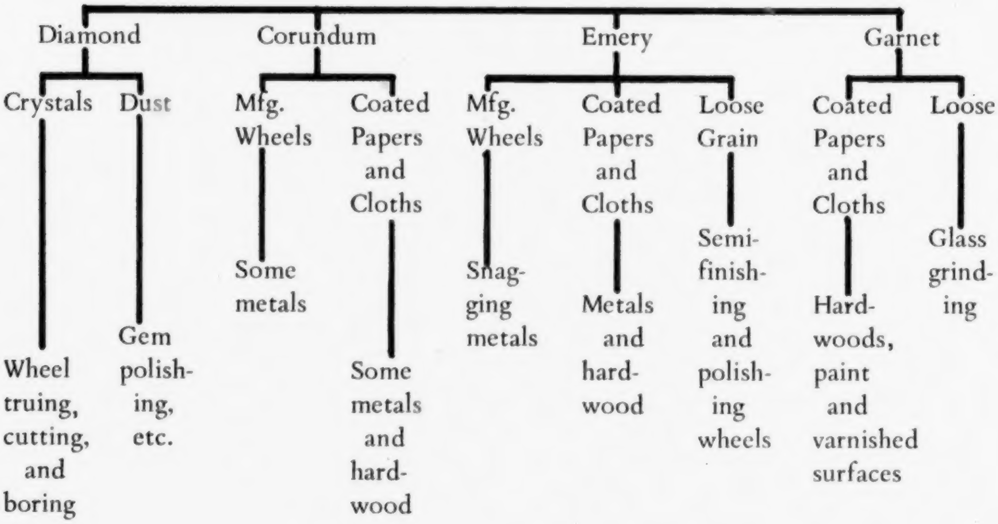
OBJECTIVE:

To learn what is meant by abrasives.

RELATED INFORMATION:

Any substance that can be used to grind away the surface of another substance is known as an abrasive. Abrasives are classed as either natural (sandstone) or artifical (silicon carbide, fused aluminum oxide, boron carbide, steel wool). Cutting, grinding and polishing operations can be performed on varying objects. To take care of the varying hardnesses and toughnesses that the abrasive must face, different types and styles must be used.

The chart that follows shows the natural hard abrasives and their uses:

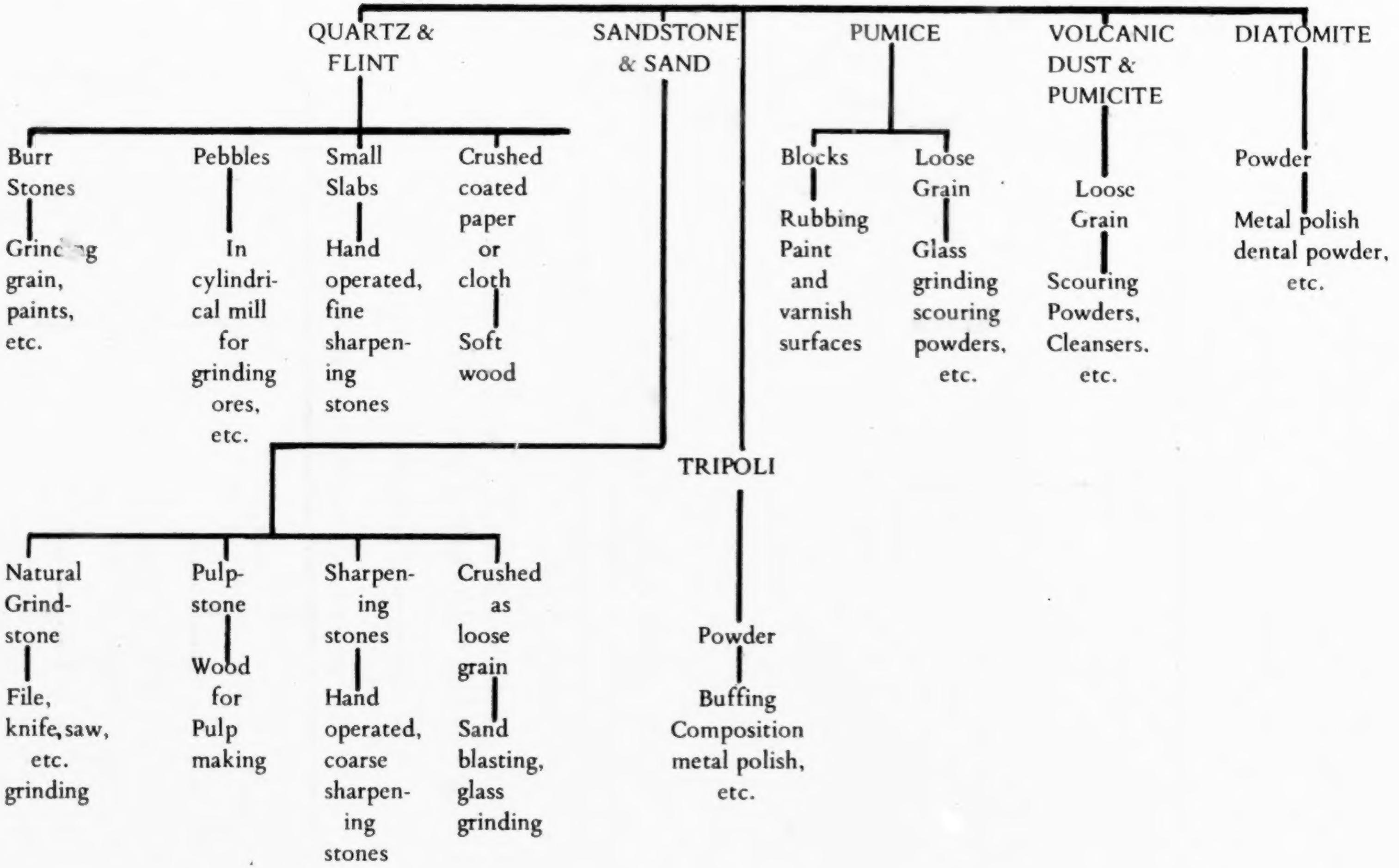

Diamond
Corundum
Emery
Garnet
Crystals
Dust
Mfg. Wheels
Coated Papers and Cloths
Mfg. Wheels
Coated Papers and Cloths
Loose Grain
Coated Papers and Cloths
Loose
Wheel truing, cutting, and boring
Gem polishing, etc.
Some metals
Some metals and hardwood
Snagging metals
Metals and hardwood
Semi-finishing and polishing wheels
Hardwoods, paint and varnished surfaces
Glass grinding

As you can notice, the diamond is used where great hardness is required in cutting tools. Corundum is used also in a grain form for glass grinding. There are three grades of emery, Grecian, Turkish, and American. The Grecian emery is hard and sharp and is used where grinding temperatures are high. Turkish emery is slightly softer and more brittle than the Grecian material. It is used in glass grinding and polishing because of its tendency to break under pressure and form fresh, sharp-edged crystals. The American variety which is much softer than the others finds its chief use on wood and soft metal work. Garnet is used in between the sanding and rough polishing of plate glass.

When studying the various siliceous abrasives, remember that nearly all of them are nearly pure silica. Quartz and flint are examples of more or less silica. Small sharpening stones for hand operation include sandstones, whetstones, hones and rubbing stones. Many stones that are used in the United States are made up of a mixture of natural grits bonded by clay, water and sodium silicate. After it is mixed, the material is molded and baked. The grinding and polishing sands (pumice, tripoli, diatomite, pumicite) are tough, sharp, hard sands free of clay.

The chart that follows gives the Siliceous Abrasives and their uses.

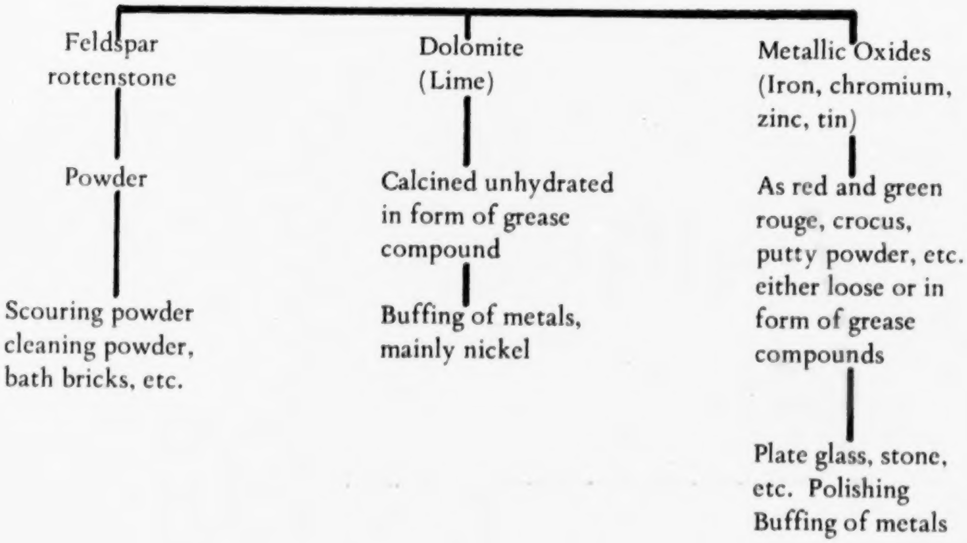
SILICEOUS ABRASIVES


QUARTZ & FLINT
SANDSTONE & SAND
PUMICE
VOLCANIC DUST & PUMICITE
DIATOMITE
Burr Stones
Grinding grain, paints, etc.
Pebbles
In cylindrical mill for grinding ores, etc.
Small Slabs
Hand operated, fine sharpening stones
Crushed coated paper or cloth
Soft wood
Blocks
Rubbing Paint and varnish surfaces
Loose Grain
Glass grinding scouring powders, etc.
Loose Grain
Scouring Powders, Cleansers, etc.
Powder
Metal polish dental powder, etc.
TRIPOLI
Powder
Buffing Composition metal polish, etc.
Natural Grindstone
File, knife, saw, etc. grinding
Pulpstone
Wood for Pulp making
Sharpening stones
Hand operated, coarse sharpening stones
Crushed as loose grain
Sand blasting, glass grinding

Soft abrasives are considered non-siliceous. Although they are softer than the materials they are working on, they smooth and polish metal and other surfaces very well.

The chart that follows lists the soft abrasives and their uses:

SOFT ABRASIVES

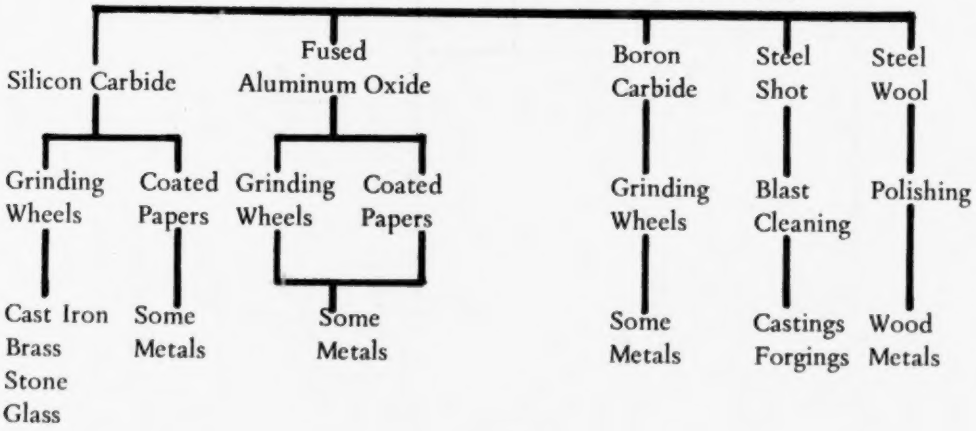

Feldspar rottenstone
Powder
Scouring powder cleaning powder, bath bricks, etc.
Dolomite (Lime)
Calcined unhydrated in form of grease compound
Buffing of metals, mainly nickel
Metallic Oxides (Iron, chromium, zinc, tin)
As red and green rouge, crocus, putty powder, etc. either loose or in form of grease compounds
Plate glass, stone, etc. Polishing Buffing of metals

The artificial abrasives listed are of greatest importance. Carborundum is a trade name for a company in Middlesex County that manufactures abrasives. Silicon carbide has a hardness between corundum and diamond (natural abrasives). It is able to withstand high temperatures without damage.

Fused aluminum oxide is similar to corundum while boron carbide is a highly heat-resistant material harder than silicon carbide.

Listed below are the artificial abrasives and their uses:

ARTIFICIAL ABRASIVES AND THEIR USES


Silicon Carbide
Grinding Wheels
Cast Iron Brass Stone Glass
Coated Papers
Some Metals
Fused Aluminum Oxide
Grinding Wheels
Coated Papers
Some Metals
Boron Carbide
Grinding Wheels
Some Metals
Steel Shot
Blast Cleaning
Castings Forgings
Steel Wool
Polishing
Wood Metals

Since both natural and artificial abrasives are used in grinding wheels and on coating papers and cloth, it would be wise for you to know some of the bonding materials.

The five types of bonds used in the manufacture of grinding wheels are *vitrified, silicate, shellac, synthetic resin* and *rubber.*

The *vitrified bond* is a mixture of ceramic raw materials, water and abrasive grain which is molded, dried, and fired in a kiln until a glossy bond develops. This bond is very strong, resists chemicals and can take moderate temperature changes.

The *silicate bond* is made by mixing a sodium silicate solution and abrasive. Evaporation causes a hardening reaction which is followed by a baking step. This wheel is softer and less heat-resistant than the vitrified type, but finds use in sharpening knives and edge tools.

The mixing of the grit of an abrasive with melted shellac and allowing it to cool, forms the *shellac bond.* The solid mass is broken into lumps to be melted into molded shapes. Shellac wheels can be recognized by their thinness and are used only on very fine work.

Synthetic resins are prepared according to the resins used. The prepared wheels can be made to travel at high speeds and have varied applications.

Rubber-bonded wheels are used only at high speeds because of the necessity of generating heat to melt the rubber and abrasive away.

Coated papers and cloth are made by sifting the abrasive onto the covering of soft glue applied to paper or cloth. After drying, the sheet gets another coating of very thin glue to bond the abrasives. These materials have many uses in the metal trades.

ABRASIVES

SHOP__________ NAME ________________________________

CLASS__________ INFORMATION SHEET NO. 1-3

PROBLEM

Match column (A) with column (B)

		(A) – Abrasive		(B) – Use
______	1.	Diamond crystals	a.	metals and hardwood
______	2.	Diamond dust	b.	softwood
______	3.	Emery cloth	c.	metal polish
______	4.	Garnet loose grain	d.	rubbing paint and varnish
______	5.	Flint paper	e.	buffing
______	6.	Sandstone	f.	knife sharpening
______	7.	Tripoli	g.	wheel truing
______	8.	Pumice	h.	glass grinding
______	9.	Diatomite	i.	gem polishing
_____	10.	Rottenstone	j.	scouring powder

INDUSTRIAL MATERIALS

PLASTICS

Strength of Materials – Machinists – Unit I Job Sheet No. 3

OBJECTIVE:

To learn the various types of plastics and their advantages.

WANTED:

The difference in thermoplastics and thermosetting plastics.

RELATED INFORMATION:

Plastics are new materials of construction for which an increasing number of industrial uses are being found. Plastics get their name from their masses which are capable of being shaped by flow of the material. Whatever their properties or form, plastics all fall into one of two groups – the *thermoplastic* (Fig. 1) or the *thermosetting* (Fig. 2).

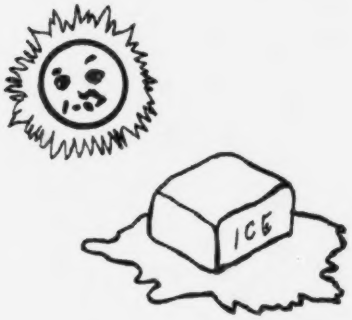


FIG. 1 THERMOPLASTIC

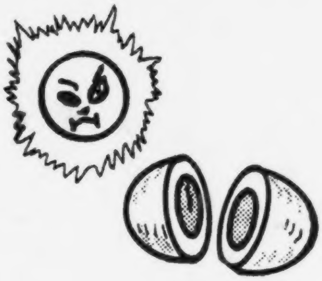


FIG. 2 THERMOSETTING

The *thermoplastic* group has plastics which become soft when exposed to sufficient heat and harden when cooled, no matter how often the process is repeated. Melting of ice and freezing of water is comparable to a thermoplastic action.

The plastic materials belonging to the *thermosetting* group are set into permanent shape when heat and pressure are applied to them during forming. Reheating will not soften these materials. An example of a thermosetting action is the hard-boiling of an egg.

The widespread and growing use of plastics in almost every phase of modern living is due in large part to their many combinations of advantages. These advantages are light weight, range of color, good physical properties, ease of use in mass-production methods, and they can be produced in most cases at lower cost than metal or wood.

TOOLS AND MATERIALS:

Boiling water, thermoplastic and thermosetting plastics.

PROCEDURE:

1. Put a piece of thermoplastic material in boiling water. Notice what happens and record on your paper.
2. Put piece of thermosetting plastic material in boiling water. Notice if anything happens and record on your paper.
3. Ask your machine shop instructor to explain the proper cutting tools and speeds for the machining of plastics. List the tools and speeds.

PLASTICS

SHOP ____________________ NAME ____________________________________

CLASS ____________________ JOB SHEET NO. 1-3

QUESTIONS

1. List the advantages of plastic.

2. What is a thermoplastic?

3. Give an example of a thermoplastic action.

4. Describe what is meant by thermosetting plastics.

5. Give an example of a thermosetting action.

INDUSTRIAL MATERIALS

RUBBER

Strength of Materials – Machinists – Unit I Job Sheet No. 4

OBJECTIVE:

To learn some characteristics of rubber.

WANTED:

Comparison of synthetic and natural rubber.

RELATED INFORMATION:

To begin with, rubber is a reliable material. It can be pulled or squeezed far out of its original shape and be depended upon to return, not once, but many times. Also, for an elastic product, it is strong and durable.

Rubber has many uses. It can be

1. Soft as the nipple on a baby's bottle
2. Hard as a bowling ball
3. Airtight for inner tubes
4. Ventilated with millions of air cells for foam cushioning
5. Made into raincoats to shed water
6. Made to pick up water in sponges
7. Made into rubber balls to bounce
8. Made into rubber shock absorbers to prevent bounce
9. Made to resist wear in automobile tires
10. Made to wear away in pencil erasers

These are the things that make rubber such a fascinating material.

TOOLS AND MATERIALS:

Black and white samples of natural rubber, and a sample of synthetic rubber.

PROCEDURE:

1. Try stretching the samples. Do they differ in stretch ability?

2. Try tearing the samples. Which seems tougher?

RUBBER

SHOP ____________________ NAME ____________________________________

CLASS ____________________ JOB SHEET NO. 1-4

QUESTIONS

1. State several physical characteristics of rubber.

2. Name five uses of rubber.

3. What did you find in sampling natural and synthetic rubber?

Ask your instructor for Achievement Test No. 1 after you complete the work in Unit I.

THE PRODUCTION OF IRON AND STEEL

BLAST FURNACE RAW MATERIALS

Strength of Materials – Machinists – Unit II Information Sheet No. 1

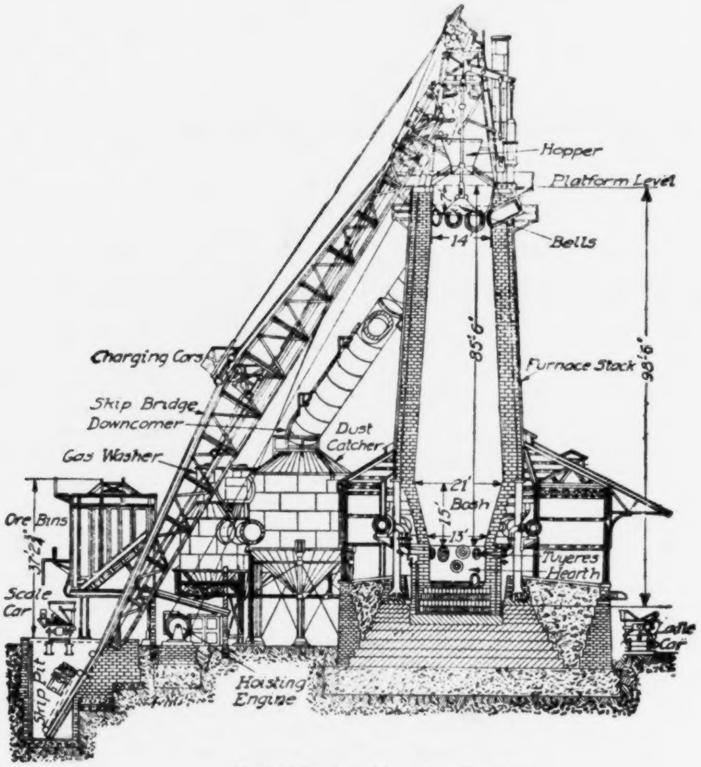
OBJECTIVE:

To learn the raw materials and their use in the blast furnace.

RELATED INFORMATION:

Since the beginning of the century, iron and steel rate as the most important materials produced for construction purposes. With the properties of the materials depending upon the method of manufacture, it is important that you know the processes for making the various iron and steel products. Then, you as a machinist can safely proceed to specify and work upon materials suited for the job.

The initial step in producing iron from iron ore is the blast furnace. (See Fig. 1). Iron ore, coke, limestone, preheated compressed air, and cooling water are the raw materials used in the furnace to produce the various grades of pig iron, slag, and blast-furnace gas.


Hopper
Platform Level
Bells
14'
85'6"
98'6"
Furnace Stack
Charging Cars
Skip Bridge
Downcomer
Dust Catcher
Gas Washer
Ore Bins
37'2"
21'
Bosh
15'
13'
Tuyeres
Hearth
Scale Car
Ladle Car
Skip Pit
Hoisting Engine

Vertical Section of Iron Blast Furnace

BLAST FURNACE – FIG. 1

Any iron-bearing mineral from which iron may be taken at a profit is an iron ore.

The iron ores as mined are made up of the pure minerals (either hematite, magnetite, siderite, or pyrite) and in varying amounts of non-iron-bearing substances known as the "gangue" of the ore.

An ore of good value is judged by:

1. Cost of mining
2. Location in relation to other raw materials used in the blast furnace.
3. Ease of transporting of raw materials and finished products.
4. Location of iron and steel product markets.

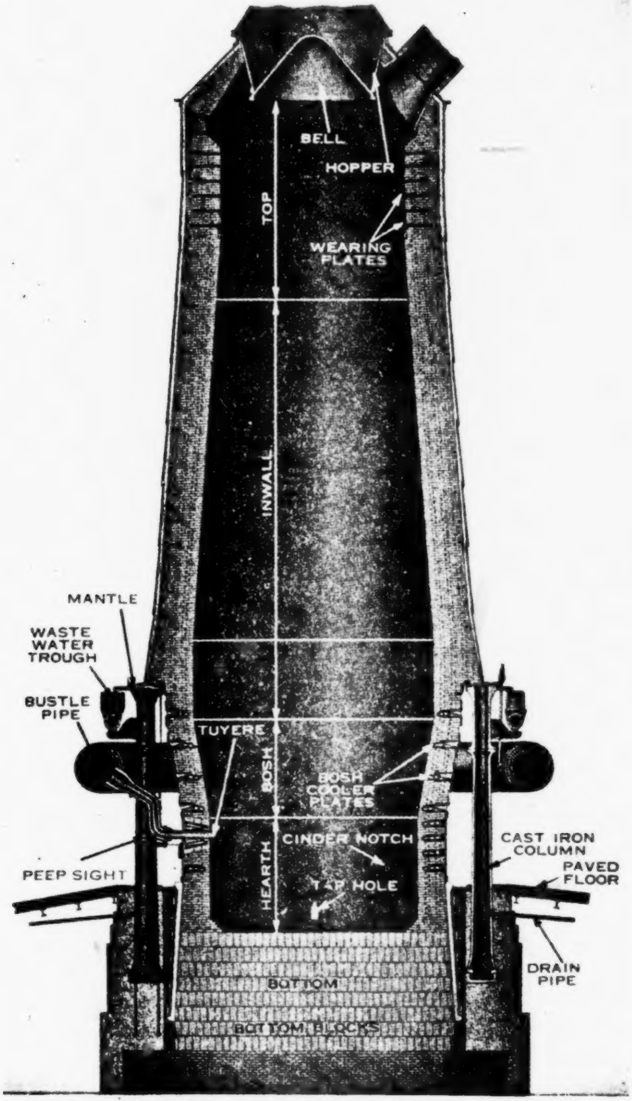
In other words, an ore, like the lower grade Alabama ores, can compete with the higher grade Lake Superior ores because ore, coal, and limestone are located close together in the vicinity of Birmingham.

In the earliest blast furnaces, wood charcoal was used as the fuel for proper temperature. As the iron industry expanded and forests were cut down, other cheap fuels were used. Since the latter part of the 19th century, charcoal and anthracite (hard coal) have given way to coke as the fuel.

Limestone is made a part of the blast-furnace charge to properly flux the silica in the ore and coke and to make a basic slag to control amounts of sulfur and silicon in the pig iron.

The importance of air in the blast furnace can only be realized when one finds 8,500 lbs. of air is needed for every ton of pig iron made. Air must be supplied for the combustion of coke in the blast-furnace charge. It is forced through *tuyeres,* short, special pipes arranged around the furnace (see Fig. 2), near the bottom of the furnace at pressures ranging from 15 to 25 psi (pounds per square inch) after preheating to temperatures of between 1000 to 1300° F.

Finally, the modern blast furnace requires much water for cooling the bosh. Notice the inverted frustum of a cone appearance which retards the settling movement of the charge until melting can take place (see Fig. 1), and the tuyeres, and for scrubbing dust from blast-furnace gas. A furnace making 1000 tons of pig iron in a 24-hour cycle uses 6 to 8 million gallons of water.


BELL
HOPPER
TOP
WEARING PLATES
INWALL
MANTLE
WASTE WATER TROUGH
BUSTLE PIPE
TUYERE
BOSH
BOSH COOLER PLATES
CINDER NOTCH
HEARTH
TAP HOLE
CAST IRON COLUMN
PEEP SIGHT
PAVED FLOOR
DRAIN PIPE
BOTTOM
BOTTOM BLOCKS

—**Design of a modern** blast furnace. (*From "Modern Refractory Practice, Harbison-Walker Refractories Co.*)

FIG. 2

BLAST FURNACE RAW MATERIALS

SHOP ____________________ NAME ____________________________________

CLASS ____________________ INFORMATION SHEET NO. 2-1

QUESTIONS

1. Define iron ore.

2. What furnace is used in the initial step to produce iron from iron ore?

3. Name the raw materials used in the blast furnace.

    a.

    b.

    c.

    d.

    e.

4. Give a reason for use of each of the raw materials in the blast furnace.

    a.

    b.

    c.

    d.

    e.

5. How is an ore of good value judged?

    a.

    b.

    c.

    d.

THE PRODUCTION OF IRON AND STEEL

BLAST FURNACE

Strength of Materials – Machinists – Unit II Information Sheet No. 2

OBJECTIVE:

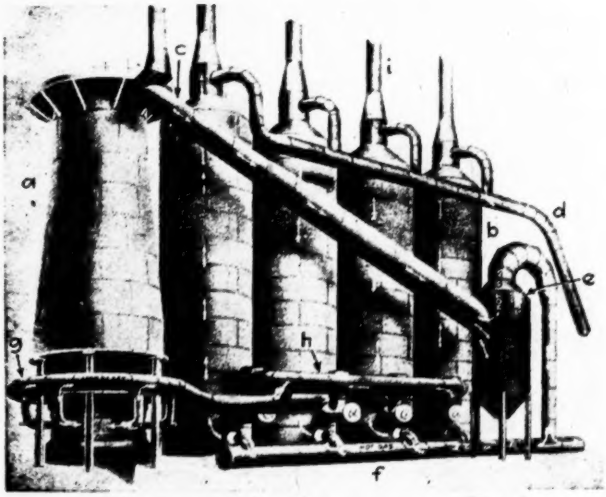
To learn how iron ore is reduced to iron in the blast furnace.

RELATED INFORMATION:

About the middle of the last century, the modern type of blast furnace came into general use.

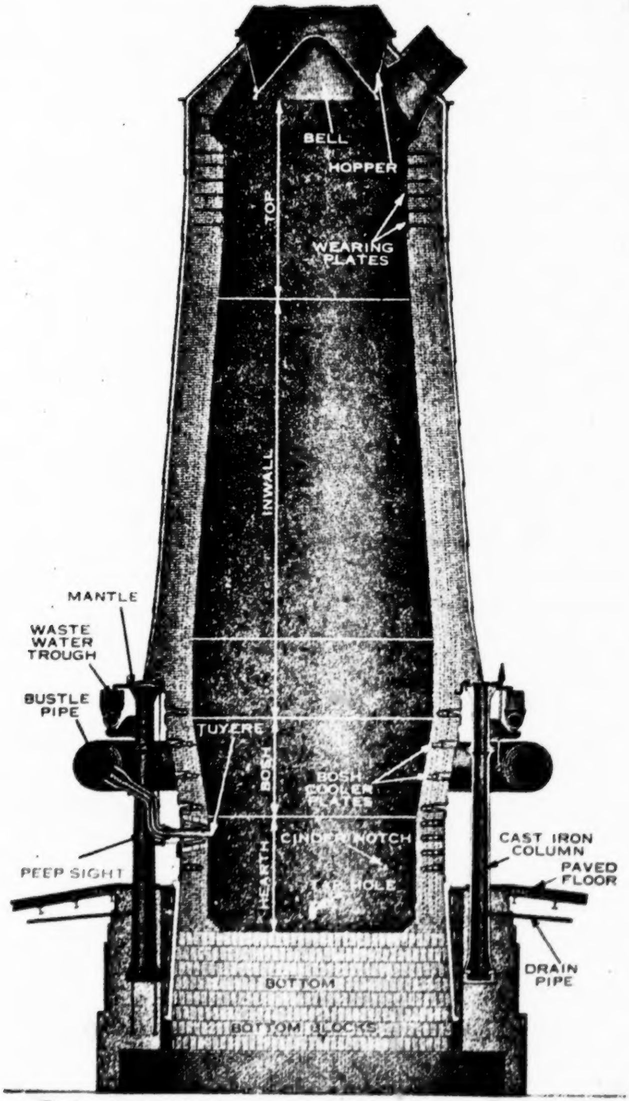
The modern blast furnace plant includes: (See Figs. 1 and 2)

1. Blast furnace
2. Stoves for preheating the blast
3. Blowing engines to supply the blast
4. Raw materials storage bins
5. Cooling water pumps and mains
6. Gas cleaning equipment
7. Boilers to use the gas not consumed in stoves
8. Blowing engines
9. Slag cars
10. Pig iron ladles
11. Pig casting machine
12. Minor accessories



—Blast-furnace unit with four stoves. *a.* Blast furnace.
Stoves. *c.* Down-comer pipe. *d.* Cold-air pipe. *e.* Dust catcher.
Hot-gas pipe. *g.* Bustle pipe. *h.* Hot-blast pipe. *i.* Stack.

FIG. 1


BELL
HOPPER
TOP
WEARING PLATES
INWALL
MANTLE
WASTE WATER TROUGH
BUSTLE PIPE
TUYERE
BOSH
BOSH COOLER PLATES
CINDER NOTCH
TAP HOLE
HEARTH
PEEP SIGHT
CAST IRON COLUMN
PAVED FLOOR
DRAIN PIPE
BOTTOM
BOTTOM BLOCKS

—**Design of a modern** blast furnace. *(From "Modern Refractory Practice, Harbison-Walker Refractories Co.)*

FIG. 2

When a blast furnace is to be "blown in" (started), it must be thoroughly dried before the regular charge can be put into it. Gradually, small charges of ore, coke, and limestone in proper proportions to the desired grade of pig iron are added until the furnace is full. Skip cars haul the materials and dump them into the receiving hopper. These skips are regulated so that the furnace, once started, never stops except for repairs, labor troubles, lack of a market for iron, or for some special reason.

A hot blast of air preheated in the stoves is supplied through the tuyeres (see Fig. 1). As the process advances, the molten iron and slag collect in the hearth. The heavier iron settles to the bottom and is drawn from the tap hole (see Fig. 2) near the bottom of the hearth every four or five hours. The slag floats on the top and is drawn from the cinder notch which is higher up about every two hours (see Fig. 2).

As the iron leaves the furnace through trenches (runners), it flows to ladles. Pig iron is taken in the ladles to the pig casting house or to the hot metal mixer where it is kept in a molten state for use in one of the steelmaking processes.

Slag is put into slag cars for transportation to the slag dump for use as crushed stone, gravel, or part of cement, or is led to the granulating pit for use as a raw material in the making of fireproof and heat-insulating materials.

The blast furnace gas that is produced leaves the top of the furnace through offtakes leading into the downcomer which takes the gas to the dust-removal equipment. (see Fig. 1).

The iron that is obtained from the furnace contains a small percentage of carbon and varying amounts of silicon, sulphur, phosphorus, and manganese, the amount being governed to some extent by the operation of the furnace and depending upon the future use of the pig iron.

As you can understand by now, the first product from the iron ore is pig iron. The first process of extracting the iron from the ore is the blast furnace. The pig iron is the raw material from which all other irons and steels are made.

BLAST FURNACE

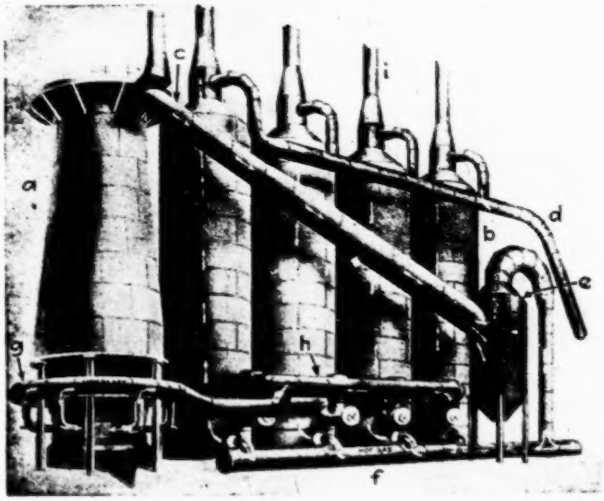
SHOP ____________________ NAME ______________________________

CLASS ____________________ INFORMATION SHEET NO. 2-2

QUESTIONS

1. Name the various parts of the blast furnace unit with four stoves.

   a.
   b.
   c.
   d.
   e.
   f.
   g.
   h.
   i.



2. Name the reasons for stopping the furnaces once they are started.

   a.
   b.
   c.
   d.

3. Why is pig iron kept in a hot metal mixer?

4. Give several uses for the slag resulting from this process.

   a.
   b.
   c.

5. How is the amount of carbon, silicon, sulphur, etc. determined for the iron to be obtained?

THE PRODUCTION OF IRON AND STEEL

PUDDLING FURNACE

Strength of Materials – Machinists – Unit II   Information Sheet No. 3

OBJECTIVE:

To learn how wrought iron is produced.

RELATED INFORMATION:

Wrought iron is produced in what is known as a puddling furnace (see Fig. 1 and 2).

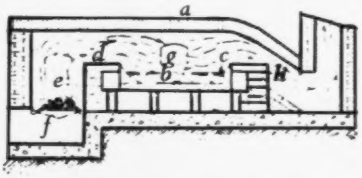
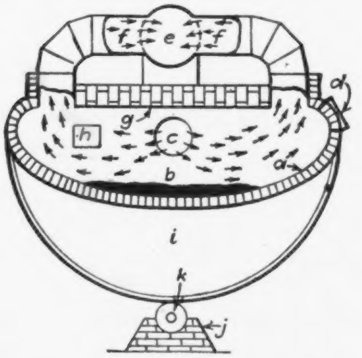


FIG. 1

MODERN HAND-PUDDLING FURNACE

a. Roof
b. Charge
c. Hearth lining
d. Bridge
e. Furnace
f. Ash pit
g. Charging door
h. Altar



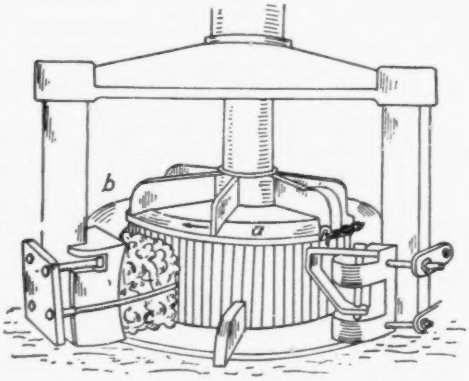
MECHANICAL PUDDLER a. Fire-brick lining. b. Bath. c. Gas intake. d. Discharging door. e. Waste gas flue to regenerative chambers. f. Gas flues. g. Roof. h. Charging door. i. Rocker. j. Foundation. k. Pinion.

FIG. 2

In the hand puddling process, the operator (puddler) moves the pig iron about to expose all parts evenly to the reducing flames.

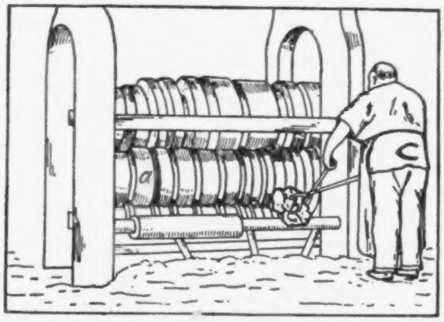
In the mechanical process, the furnace rocks, and causes the metal to flow back and forth over the hearth. The motion has the same effect on the iron as the hand puddling process.

In the puddling furnace the combustion takes place at one end only. The furnace is lined with iron oxide which eliminates, in melting, the carbon from the charge of cold pig iron. With the removal of nearly all the carbon and other impurities through hand or mechanical puddling, the metal begins to form a pasty mass. This pasty mass of metal and slag is stirred until it is formed into or forms a ball. Upon removal from the furnace, the bulk of the slag is squeezed from the mass by means of a mechanical squeezer. (see Fig. 3)



a. Toothed cylinder.
b. Housing. c. Wrought-iron ball.

MECHANICAL SQUEEZER
FIG. 3



a. Rolls. b. Work.

BAR MILL
FIG. 4

The iron is rolled into bars in the bar mill (see Fig. 4). These bars are cut into short lengths, piled and wired together, heated to welding heat and rolled into the desired shapes. The purpose of the stacking and rerolling is a better distribution of the slag.

The Aston-Byers process has been developed for the manufacture of synthetic wrought iron. This process uses steelmaking furnaces to produce a material differing only in that it can be welded more easily than the iron produced by the puddling process.

The principal value of wrought iron is its ability to resist corrosion and fatigue failure. Because of its softness and ductibility, it finds use as bolts, pipe, tubing, nails, ornamental railing, etc.

PUDDLING FURNACE

SHOP ____________________ NAME __________________________________

CLASS ____________________ INFORMATION SHEET NO. 2-3

QUESTIONS

1. What is the puddling furnace lined with? Why?

2. How is the bulk of the slag removed from the pasty mass that is taken out of the furnace?

3. Why are the bars stacked, reheated and rerolled?

4. What does the Aston-Byers process produce?

5. Name several uses of wrought iron.

    a.

    b.

    c.

THE PRODUCTION OF IRON AND STEEL

BESSEMER PROCESS

Strength of Materials – Machinists – Unit II   Information Sheet No. 4

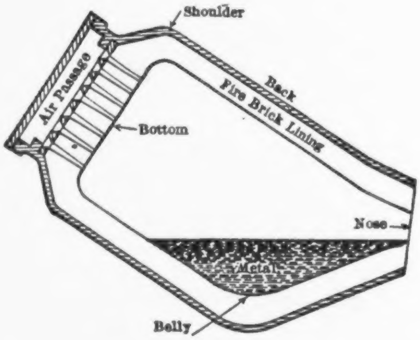
OBJECTIVE:

To learn how steel is made in the bessemer process.

RELATED INFORMATION:

In making Bessemer steel, molten iron from the blast furnace is poured into the converter as it is tilted on its side. (see Fig. 1)

Righted, air is blown through a number of holes in the bottom of the converter. The silicon and manganese in the molten iron are oxidized with some iron oxide. The mixture rises to the top to form a slag. A brilliant flame shooting from the end of the converter signals that the carbon has started to burn. When the flame gradually dies down, it shows that the impurities have burned off.



CROSS-SECTION OF TILTED BESSEMER CONVERTER
FIG. 1

The vessel is tilted again. A charge made up of:

1. the amount of carbon needed to bring a specified carbon content,
2. manganese to act against the sulphur, and
3. silicon to take care of the gases

is added to the molten metal.

The finished steel is poured into a large ladle. From the ladle, it is poured into ingot molds for future use in the rolling or forging mills.

Steels made by this process are either acid or basic: acid steel, if the lining of the converter was silica,and basic, if the lining was dolomite or magnesite.

Bessemer steel is a low-carbon steel with comparatively low strength, ductibility and toughness requirements, finding use in low-grade sheets, wire, pipe, screw stock, concrete reinforcing, track spikes, and small structural shapes.

While at one time, the cost of the process was low, the lack of low-phosphorus iron ores has caused an increase in the cost of operations.

BESSEMER PROCESS

SHOP ____________________ NAME ________________________________

CLASS ____________________ INFORMATION SHEET NO. 2-4

QUESTIONS

1. What signals that the carbon has started to burn?
2. Why is air blown through the molten iron?
3. When does the operator recharge the converter?
4. Give the composition of the recharge of the converter.
    a.
    b.
    c.
5. What types of steel are produced? Why?
    a.
    b.
6. Give the characteristics of Bessemer steel.
7. Name five uses of Bessemer steel.
    a.
    b.
    c.
    d.
    e.
8. Why has the cost of producing steel by this process been increased?

THE PRODUCTION OF IRON AND STEEL

OPEN-HEARTH PROCESS

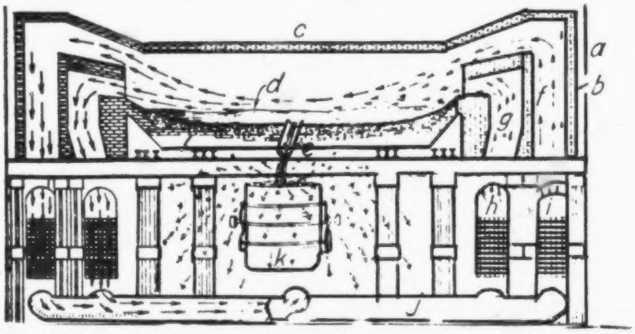
Strength of Materials – Machinists – Unit II   Information Sheet No. 5

OBJECTIVE:

To learn how steel is made in the open-hearth process.

RELATED INFORMATION:

The making of a typical basic open-hearth steel follows:



CROSS-SECTION OF OPEN-HEARTH FURNACE
FIG. 1

1. Furnace (see Fig. 1) is heated with gas flame to make it dry.
2. Calcined dolomite is thrown over floor and walls of furnace.
3. Furnace is mechanically charged with limestone, iron ore and steel scrap.
4. Molten iron is added after steel scrap begins to melt (about two hours).
5. Thin slag formation is removed.
6. Heating is continued until scrap melts.
7. Limestone starts to dissolve into carbon dioxide and calcium oxide.
8. The rising gas forms a thick slag at the surface.
9. Continued heating lowers carbon content to desired percentage.
10. Bath is brought to proper temperature for tapping and pouring.
11. After metal is in ladle, ferromanganese or ferrosilicon is added if a low-carbon or soft steel is desired. Higher carbon steels are made before tapping by adding molten iron and ferro alloys to achieve the desired carbon content.

Structural, copper-bearing, spring, boiler, flange, rail, pipe, welding, strip, forging and sheet steels plus sheet bar, tin bar, hoop iron, and screw stock are all products of the basic open- hearth process, while the bulk of the acid open-hearth process steel is used for forgings and steel castings.

From time to time tests are taken to indicate to the operator how much progress has been made in the steel making process. When the metal has reached the quality required, the furnace is brought to the proper temperature for tapping and pouring.

The make-up of the charge, furnace type and size, and steel quality determine the length of heating time. The usual amount of time required may vary from 5 to 12 hours.

In the acid open-hearth process no limestone is used, and the slag is formed from the iron impurities and the lining of the furnace.

OPEN-HEARTH PROCESS

SHOP ______________________ NAME ______________________________________

CLASS ______________________ INFORMATION SHEET NO. 2-5

QUESTIONS

1. Why is the open-hearth furnace heated with gas flame?

2. Give the composition of the charge.

   a.

   b.

   c.

3. How is low carbon steel obtained?

4. How is high carbon steel obtained?

5. What is eliminated from the charge in the acid open- hearth process?

6. Name five uses for the basic open-hearth processed steel.

   a.

   b.

   c.

   d.

   e.

7. Name two uses for the acid open-hearth processed steel.

   a.

   b.

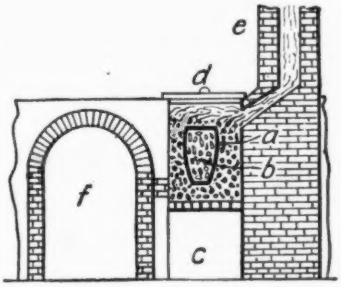
THE PRODUCTION OF IRON AND STEEL

CRUCIBLE STEEL

Strength of Materials – Machinists – Unit II | Information Sheet No. 6

OBJECTIVE:

To learn how steel is made in the crucible process.



a. Crucible. b. Charge. c. Ash pit.
d. Melting hole. e. Stack. f. Cellar

CRUCIBLE-STEEL FURNACE
FIG. 1

RELATED INFORMATION:

In the crucible process, wrought iron or good scrap iron,along with a small amount of high-grade pig iron and other materials,is placed in a clay crucible. (Fig. 1) After the charge is melted in a gas or coke-fired furnace and the gases and impurities have risen to the surface, the crucible is taken from the furnace. The slag is removed and the steel poured into a small ingot for forging.

The process offers with little or no refining a metal dependent on the purity of the charged materials. Although high-grade tool steels and some alloy steels are still made by the crucible process, steelmaking in the electric furnace is equal in quality.

CRUCIBLE PROCESS

SHOP ____________________ NAME ________________________________

CLASS ____________________ INFORMATION SHEET NO. 2-6

QUESTIONS

1. Give the composition of the crucible furnace charge.
    a.
    b.
    c.

2. Name the uses for crucible steel.
    a.
    b.

3. What process can compare in quality with the crucible?

4. When is the crucible taken from the furnace?

5. How is the standard of the metal resulting from the crucible process obtained?

THE PRODUCTION OF IRON AND STEEL

ELECTRIC FURNACE STEEL

Strength of Materials – Machinists – Unit II | Information Sheet No. 7

OBJECTIVE:

To learn how steel is made in the electric furnace.

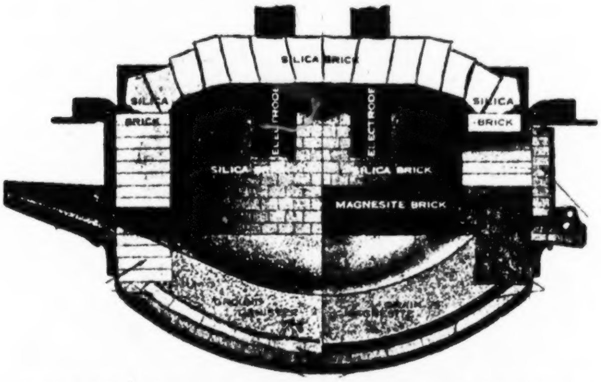
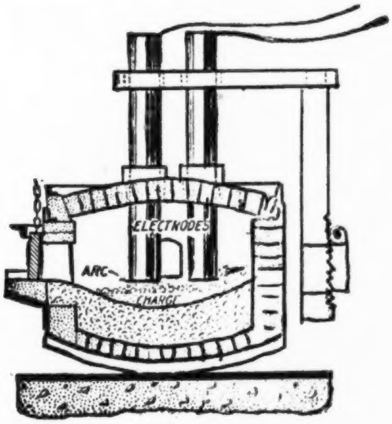

SILICA BRICK
SILICA BRICK
SILICA BRICK
ELECTRODE
ELECTRODE
SILICA BRICK
SILICA BRICK
MAGNESITE BRICK
GROUND GANISTER
GRAIN MAGNESITE

FIG. 1 – DIRECT-ARC TYPE ELECTRIC FURNACE IN SECTIONAL VIEW

RELATED INFORMATION:

The electric furnace (see Fig. 1) has proven to be an ideal melting and refining unit for the steel industry. The advantages over other steelmaking follow

1. Carbon arc does not oxidize giving pure heat in tightly closed furnace.
2. Temperature limited only by furnace lining.
3. Regulation and control easily obtained.
4. High efficiency.
5. Controlled refining and alloying.


ELECTRODES
ARC
CHARGE

In most electric furnaces the heat is produced by means of an arc above the bath or by means of arcs between the slag and electrodes suspended above the bath (see Fig. 2). The modern arc-type electric furnace is round in shape and operates on the standard three-phase, three-electrode service arc-type.

Diagram of Arc-Type Electric Steel Furnace

FIG. 2

The extreme importance of the lining of the basic electric furnace is one of the principal features of the furnace. The hearth must be made from magnesite or burned dolomite material to withstand the lime slags used in the basic process. The walls and roof must be able to withstand extremely high temperatures, silica brick meeting these requirements.

The bulk of the charge is made up of carefully selected steel scrap that will give upon melting a smaller amount of alloying elements than is required in the finished steel. Ferroalloys and carbon can be added to bring the steel up to the required content.

Tapping starts when the mixture has obtained the proper chemical elements. It is tapped into a ladle, then poured into ingot molds with the greatest of care. The ingot has to be without blowholes, shrinkage holes, etc. if at all possible.

The basic electric process has nearly taken over the market for the fine quality and special alloy steels.

As in all acid-type processes for steelmaking, phosphorus and sulfur cannot be eliminated in the acid-electric process. The difference between the acid open-hearth and acid electric processes are that the electric process has better control over all reactions and produces a cleaner steel.

ELECTRIC FURNACE STEEL

SHOP ____________________ NAME ____________________________________

CLASS ____________________ INFORMATION SHEET NO. 2-7

QUESTIONS

1. Name the advantages of the electric furnace process over other processes of steelmaking.

   a.

   b.

   c.

   d.

   e.

2. How is the heat produced in an electric furnace?

3. Explain the lining used in the basic electric furnace.

4. Name the use for the basic electric furnace steel.

5. Does the acid open-hearth or acid electric process produce a cleaner steel?

Ask your instructor for Achievement Test No. 2 after you complete the work in this unit.

PRODUCTION OF NON-FERROUS METALS

ALUMINUM

Strength of Materials – Machinists – Unit III   Information Sheet No. 1

OBJECTIVE:

To learn how aluminum is produced.

RELATED INFORMATION:

Aluminum, about twice as plentiful as iron, rates third behind oxygen and silicon in its abundance in the earth's crust.

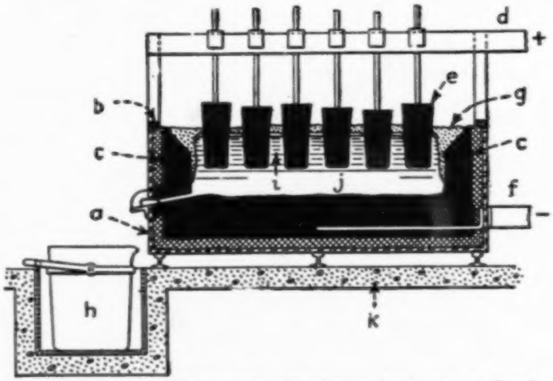
Aluminum is secured commercially from an ore known as bauxite. Bauxite ores can be found in North and South America and in Europe. France's high-grade ore supplies the bulk of Europe, while Arkansas rates ahead of Georgia as the supplier in our country.

Because bauxite is too impure to use in direct electrolytic reduction, two processes must be used.

1. Bayer process to purify ore and produce alumina.

2. Hall-Heroult process which reduces the alumina to aluminum by electrolysis.

In the Bayer process, the aluminum oxide is dissolved from the bauxite by use of caustic soda. Filtering removes the impurities. It is separated as aluminum hydrate, and calcined (reduced to a powder) to form alumina (aluminum oxide).



—Hall-Héroult electric aluminum furnace. *a.* Steel shell. *b.* Electric insulation. *c.* Carbon lining. *d.* Bus bar. *e.* Carbon (positive) electrodes. *f.* Negative connection (collecting plate). *g.* Frozen crust of electrolyte and aluminum. *h.* Ladle. *i.* Molten electrolyte. *j.* Molten aluminum. *k.* Concrete floor.

CROSS-SECTION HALL-HEROULT ELECTRIC ALUMINUM FURNACE

FIG. 1

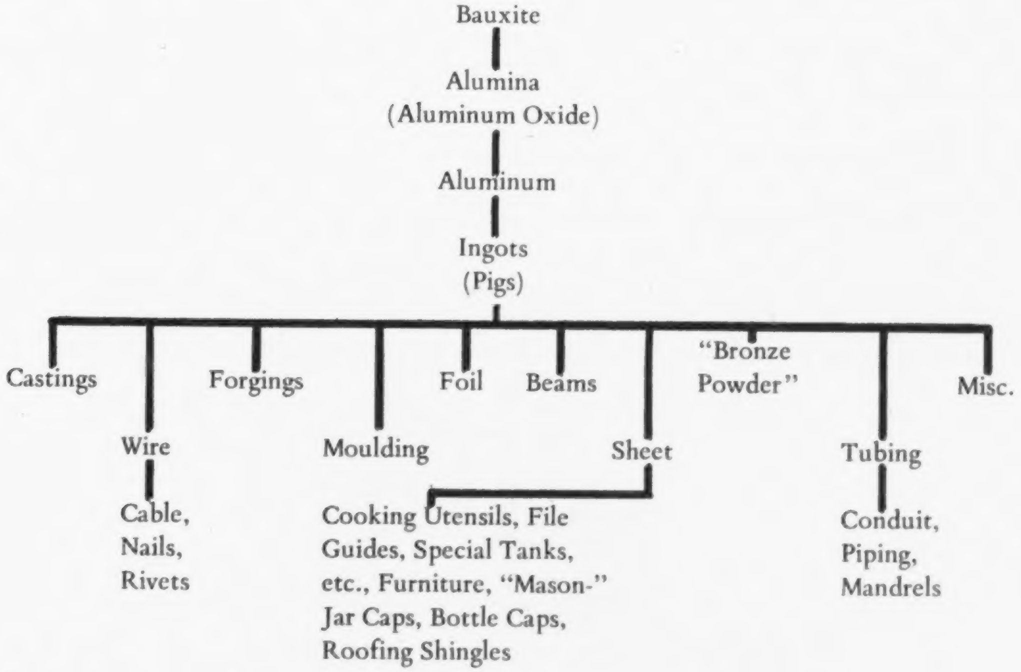
In the Hall-Heroult process an electric aluminum furnace is used (see Fig. 1). The steel shell measures about 8 feet long by 4 feet wide and 2 feet deep. Inside of a refractory lining is a baked-in mixture forming the cathode. Carbon electrodes form the anodes.

If you remember the basic science you were taught, the cathode is used as a negative charge to attract the positively charged aluminum, while the anodes being positive will attract the negative oxygen in the aluminum oxide mixture in the furnace. The oxygen forms into carbon monoxide and burns off as a gas.

Alumina is added every so often to the furnace. The aluminum is drawn from the bottom of the furnace every day or two making the process a continuous one.

Pure aluminum is too soft for practical purposes. As an alloy, it has many applications in cast and wrought products.

ALUMINUM


Bauxite
Alumina
(Aluminum Oxide)
Aluminum
Ingots
(Pigs)
Castings
Wire
Cable,
Nails,
Rivets
Forgings
Moulding
Foil
Beams
Sheet
Cooking Utensils, File
Guides, Special Tanks,
etc., Furniture, "Mason-"
Jar Caps, Bottle Caps,
Roofing Shingles
"Bronze
Powder"
Tubing
Conduit,
Piping,
Mandrels
Misc.

ALUMINUM

SHOP ____________________ NAME ____________________________________

CLASS ____________________ INFORMATION SHEET NO. 3-1

QUESTIONS

1. Name the ore from which aluminum is extracted.

2. Where is the ore found in the United States?
    a.
    b.

3. Identify the processes used to produce pure aluminum.
    a.
    b.

4. What is the chemical name for aluminum?

5. What is a disadvantage of pure aluminum?

6. State the applications of aluminum as an alloy.
    a.
    b.

7. Why can't bauxite be used in direct electrolytic reduction?

PRODUCTION OF NON-FERROUS METALS

COPPER

Strength of Materials – Machinists – Unit III Information Sheet No. 2

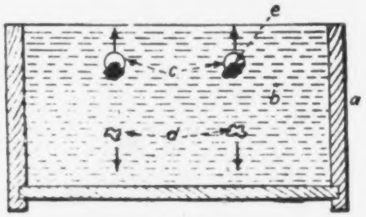
OBJECTIVE:

To learn how copper is produced.

RELATED INFORMATION:

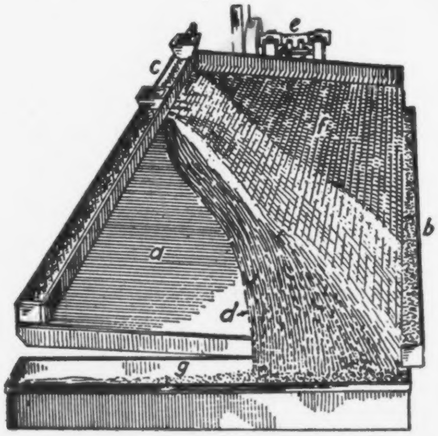
Copper ores can be found scattered over the face of the earth. United States, Chile, and Africa are ranked according to their place in the mining of the ore.

Before copper ore can be smelted at a profit, the separating of the ore and worthless rock is necessary through a floatation machine (see Fig. 1) or a concentration table (see Fig. 2).



Principle of floatation
a. Tank b. Solution c. Air bubble
d. Worthless rock e. Richer ore

FIG. 1



Ore-concentrating table. a. Table. b. Launder. c. Feed. d. Concentrates. e. Shaking mechanism. f. Slime. g. Concentrate box.

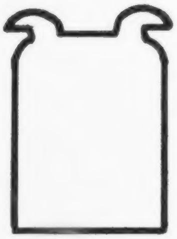
FIG. 2

The generally used floatation process causes the richer pieces of ore to float. The finely powdered ore is put into a tank containing a solution of water, pine oil and some chemicals. The solution is stirred and creates little air bubbles covered with oil. The oil-covered bubbles attach themselves to the richer pieces of ore as they float to the surface of the tank. The ore is filtered and roasted to remove as many impurities as possible.

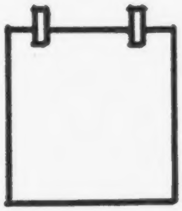
In the concentration process, finely crushed ore is run on the tables in water. A jerking motion causes the heavier material to collect in grooves and pass out at each end of the table. The lighter materials are forced over the ridges and pass off at one side.

Smelting of copper starts in a reverberatory furnace (similar to open-hearth furnace). The fuel used may be pulverized coal or fuel oil. The result of smelting is a crude copper matte which in the molten state goes to the converters or oxidizing furnaces for further refining.

A typical converter works in a similar manner to the Bessemer converter. The blister-like appearing product is nearly pure copper. The blister copper goes through continued refining in reverberatory furnaces. The copper is cast into anodes similar to the one shown in Fig. 3.



750 LB. ANODES
FIG. 3



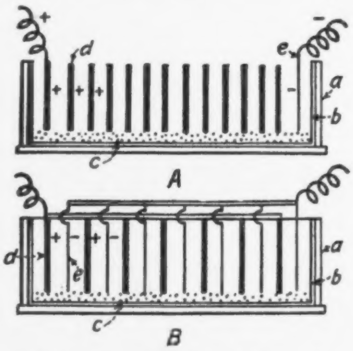
THIN, ALMOST PURE COPPER SHEETS
FIG. 4

The next to last step is to remove all remaining foreign metals by electrolysis. In the electrolytic process, a typical plant is equipped with lead-lined tanks, fitted on the top edges to supply electricity. Copper sulphate and sulphuric acid partly fill the tank. Into the tanks go anodes and cathodes (see Fig. 4), to hang in such a way as to form the positive and negative poles of an electric current.

The multiple and series methods are used to arrange the copper castings and sheets. A current of 7,000 amperes is sent through the solution, which dissolves the copper from the anodes and deposits it on the cathodes.

The gold, silver, arsenic, and other non-copper metals are released. They settle to the bottom of the tank in the form of slime, which is cast for refining.

When the cathodes have increased their weight to about 170 pounds, they are replaced by new, thin starting sheets.



Electrolytic copper-refining tanks or cells. A Series process. B. Multiple process. a. Wooden or cement tank. b. Lead lining. c. Slime. d. Anodes. e. Cathodes.

FIG. 5

The product, about 99.98% pure, is ready for final melting and refining in large reverberatory furnaces. The steps consist of:

1. Charging – Machine puts cathode in sheets in furnace.

2. Melting – Blending of copper.

3. Oxidizing – Cuprous oxide is added to the molten copper to oxidize all impurities.

4. Poling — With a covering of coke or charcoal over the bath, poling begins. Butt ends of green poles are forced underneath the surface of the metal. The violent action causes a reduction of the dissolved cuprous oxide.

5. Casting — Molten copper cast into commercial shapes.

Most of the copper produced is used for electrical purposes. About one-fourth is used in making brass, bronze, and other copper alloys.

COPPER

SHOP ____________________ NAME ________________________________

CLASS ____________________ INFORMATION SHEET NO. 3-2

QUESTIONS

1. Name several places where copper ore is found.

   a.
   b.
   c.

2. State two methods used to separate the ore and worthless rock.

   a.
   b.

3. What furnaces are used in various steps of producing copper?

   a.
   b.

4. How pure is the product after the electrolytic process?

5. Name several uses for copper.
   a.
   b.
   c.

PRODUCTION OF NON-FERROUS METALS

LEAD, TIN, ZINC

Strength of Materials – Machinists – Unit III   Information Sheet No. 3

OBJECTIVE:

To learn how lead, tin and zinc are produced.

RELATED INFORMATION:

An ore known as galena and containing lead sulphide, zinc, copper, silver, arsenic, iron, and other metals is found in great abundance in the western part of the United States.

Mining of lead follows steps similar to those of copper mining. The concentrates are calcined (made powdery by heat action) to remove the sulphur and melted together for smelting. Mixed with flux and coke and smelted in a blast furnace, similar to iron-ore smelting, a lead bullion containing lead and some of the other metals is obtained.

Continued refining of the lead bullion by removing the copper, arsenic, iron, silver and other metals gives a lead nearly 100% pure.

Lead can be used for sheets, pipes, tank linings, tubes, cable coverings, foil, battery plates, bullets and enamels. Alloyed with tin, it makes solder, while lead, tin, and antimony make bearing or type metal. Oxidizing the lead gives white and red lead.

Tin ore must be concentrated like the previous non-ferrous metals before it can be smelted. The concentrates are prepared for smelting according to the impurities they may contain.

When sulfur is present,roasting takes place to remove it. Other impurities are oxidized and washed out by an acid and hot-water treatment.

The tin oxide must be smelted in a reducing furnace (reverberatory) in the presence of a flux of carbon. So that as much tin can be released as possible, a limestone flux is also used. Because a lot of tin passes off through vaporization, the waste-gas flues are connected with a recovery system.

The tin bullion is refined,and a cleaning process in large kettles causes the impurities to rise to the surface, where they are removed. The tin is cast into pigs for commercial use.

Tin is used mostly for tin plate or containers.

Zinc ores are widely distributed. For the most part, after concentration, the floatation process is used. An exception is the northern New Jersey deposits, where an electro-magnet extracts the large amount of iron in the ore before it can be processed.

In extracting the metal from the concentrates, any one of three processes is used. They are:

1. Ordinary distillation
2. Electrothermal distillation
3. Electrochemical treatment

Eighty or ninety small clay retorts charged with a mixture of calcined ore and coal or coke are placed in a special furnace in the ordinary distillation process. The temperature is raised until the zinc boils and passes off as a vapor. The vapor is condensed into zinc in a special condensing chamber. The zinc is cast into commercial forms while the material left in the retorts is reworked to recover any other metal that will show a profit.

The electrochemical process uses an electric furnace to obtain the vaporizing of the metal and the follow-up is similar to the ordinary distillation process. Cost of operating the furnace is high if electricity cannot be obtained cheaply. This process is used only in Sweden where only a small percentage of zinc is refined.

The electrochemical process is divided into a leaching and separation of the zinc from a solution.

The concentrates are roasted to drive off water, sulfur and other impurities. The resulting material is treated with sulphuric acid to dissolve the zinc and precipitate the iron, copper, and other metals.

The pure solution is run into lead-lined electrolyzing tanks for separation. Lead anodes and thin sheets of aluminum cathodes are used. When the current is turned on, the zinc separates from the solution and deposits itself on the aluminum sheets. It is peeled off the sheets and is ready for casting into commercial forms. The acid solution can be used over again in the process.

Zinc is used as a galvanizing material and,alloyed with copper,makes brass. Zinc oxide finds use in paints.

LEAD, TIN, ZINC

SHOP ______________________ NAME ____

CLASS ______________________ INFORMATION SHEET NO. 3-3

QUESTIONS

1. What is the ore from which tin is extracted?

2. Where is an ore known as galena found?

3. Name some of the metals found in galena.
   a.
   b.
   c.
   d.
   e.
   f.

4. What exception in the processing of zinc ores from North Jersey deposits has to be considered? Why?

5. Name five uses of lead.
   a.
   b.
   c.
   d.
   e.

6. Why is a limestone flux used in the smelting process of tin?

7. What is tin used for?
   a.
   b.

8. Name three processes that can be used to extract zinc from the ore.
   a.
   b.
   c.

9. Which process would be too costly to use in some sections of the United States?

10. Give two uses of zinc.
    a.
    b.

PRODUCTION OF NON-FERROUS METALS

CADMIUM

Strength of Materials – Machinists – Unit III   Information Sheet No. 4

OBJECTIVE:

To learn how cadmium is produced.

RELATED INFORMATION:

Cadmium is probably the first metal that was not discovered as an ore. Cadmium is obtained as a by-product in the production of zinc and sometimes lead. It is recovered from the fumes produced in the roasting process of zinc, from the powder formed during zinc distillation, from tank solutions in the electrolytic refining of zinc, from the lead furnace fumes. Three methods of obtaining cadmium are:

1. Redistillation of zinc or lead by-products.
2. Electrolytic methods.
3. Precipitation with zinc.

Cadmium alloyed with tin, lead and bismuth forms a low-melting-point material that is used in sprinkler heads, fire alarms, electric fuses, and safety plugs in boilers. Other cadmium alloys find use in sterotype plates and rust-proof coatings.

CADMIUM

SHOP ____________________ NAME ________________________________

CLASS ____________________ INFORMATION SHEET NO. 3-4

QUESTIONS

1. How does cadmium differ from other metals with regard to its source?

2. How is cadmium obtained?

3. Give some uses of cadmium.

   a.
   b.
   c.

4. Name three methods of obtaining cadmium.

   a.
   b.
   c.

PRODUCTION OF NON-FERROUS METALS

MAGNESIUM

Strength of Materials – Machinists – Unit III Information Sheet No. 5

OBJECTIVE:

To learn how magnesium is produced.

RELATED INFORMATION:

Magnesium has become one of the most important of the non-ferrous metals because of the demand for very strong and very light metal products in aircraft design. It is malleable, ductile and possesses a high tensile strength when alloyed, but corrodes in salt water, salt air, and in most acids.

Large amounts of natural ores of magnesium (magnesite) are found in Austria, Greece, Russia, and along the Pacific Coast of North America.

At present, nearly all of the commercial magnesium is obtained by the direct electrolysis of natural salts.

The initial step in the production of magnesium is to get magnesium chloride. This salt is recovered in the purifying of sodium chloride found in salt wells or extracted from sea water.

A melted mixture of the chlorides of sodium, potassium, and magnesium is electrolyzed in an airtight iron vessel. The walls of the vessel act as a cathode, and there is a centrally located anode of graphite. As the magnesium is freed from the mixture, it rises to the surface and is ladled out.

The metal is refined by remelting it in iron pots, fluxed with sodium magnesium chloride to remove oxides. If the magnesium needs to be nearly pure, a distillation process is added.

Pure magnesium is used in the form of ingots, bars, rods, wire, tubes, ribbon, sheets, and powder. A good percentage of magnesium goes into alloys to form sheets, wire, rods and structural shapes. Magnesium powders find use in flashlight work and for various signaling devices.

MAGNESIUM

SHOP ____________________ NAME ____________________________________

CLASS ____________________ INFORMATION SHEET NO. 3-5

QUESTIONS

1. Why has magnesium become so important as a non-ferrous metal?

2. State some physical characteristics of magnesium.
    a.
    b.
    c.
    d.

3. How is commercial magnesium obtained?

4. Give several uses of pure magnesium.
    a.
    b.
    c.

5. What are two other uses for magnesium?
    a.
    b.

PRODUCTION OF NON-FERROUS METALS

NICKEL

Strength of Materials – Machinists – Unit III Information Sheet No. 6

OBJECTIVE:

To learn how nickel is produced.

RELATED INFORMATION:

The most important nickel deposits are found in the Sudbury district of Ontario, Canada. The ores are imported to the United States because only a small quantity of nickel is produced from the nickel salts recovered in the refining of blister copper.

In the Sudbury district the coarse concentrates are smelted in blast furnaces while the fine concentrates are put into a reverberatory furnace. The matte resulting from the smelting is bessemerized to remove the iron. The bessemer matte consists chiefly of copper and nickel sulfides.

The two principal processes of extracting nickel from the copper-nickel matte are:

1. Orford, wherein the product as cast from the blast furnace makes a two-layer solid. The top layer contains copper sulfide, while the bottom layer is of nickel sulphide, which is refined electrically.

2. Mond, which consists of vaporizing the cast nickel into a carbon monoxide gas and nickel.

Nickel finds great use because of its resistance to atmosphere and chemical corrosion, and the ability to take a high polish. Vats and vessels in the chemical industry and electroplating of hardware make good use of nickel, while alloys of nickel take a great amount of the metal.

NICKEL

SHOP ____________________ NAME ____________________________________

CLASS ____________________ INFORMATION SHEET NO. 3-6

QUESTIONS

1. Where are large deposits of nickel ores found?

2. State the two principal processes of extracting nickel from the copper-nickel matte.
   a.
   b.

3. Why is nickel an important non-ferrous metal?
   a.
   b.

4. Give two uses of nickel.
   a.
   b.

PRODUCTION OF NON-FERROUS METALS

ADDITIONAL NON-FERROUS METALS

Strength of Materials – Machinists – Unit III   Information Sheet No. 7

OBJECTIVE:

To learn how some of the other non-ferrous metals are produced.

RELATED INFORMATION:

Some of the remaining non-ferrous metals that will be briefly sketched as to their production methods are antimony, manganese, chromium, tungsten, molybdenum, vanadium, bismuth, cobalt, mercury, titanium, gold, and silver.

Antimony is obtained as a by-product in lead refining or by heating the ore known as stibnite with scrap iron. The pure metal does not find industrial use, but is alloyed with metals to give them hardness and the ability to be cast with sharp detail.

Manganese is another metal that is not used in its pure state. Instead, it finds use as an addition to ferrous metals and alloys to make them easier to forge. It is produced as a commercial metal by the Thermit process (reduction with aluminum) or as ferromanganese by preparation in an electric furnace.

Chromium has the advantage of being harder and more resistant to corrosion than nickel. It has replaced the latter metal in some applications of electroplating. It is prepared by the Thermit process. Chromium, also, finds use added to steel and alloyed with nickel.

The principle use of *tungsten* is in the electric light bulb as a filament. Other uses are phonograph needles, heating elements in very high temperature furnaces, and part of high-speed steel. Tungsten is obtained as an oxide from the ore. Reduction of the tungsten oxide produces a metallic tungsten powder. The hot powder is placed in dies and pressed. By repeated heating and hammering, a solid bar of metal is obtained.

To produce *molybdenum,* an ore, molybdenite, is concentrated by a floatation process, roasted, and reduced by carbon in an electric furnace. The chief use of the metal is in the manufacture of high-tensile steels.

Vanadium is used mainly in the making of vanadium steel for use as springs or hand tools. The making of pure vanadium is difficult and very little is produced for commercial purposes. Rather, the reduction of the ore (patronite) and flux is done in an electric furnace.

Bismuth is a by-product of the lead-refining process. Combined with lead, tin and cadmium to form a low-melting alloy, it finds similar uses to cadmium on sprinkler heads, fire alarms, etc.

Cobalt, similar to nickel, is used as a part of certain special steels.

Mercury is the only common metal that is liquid at ordinary temperatures. It is produced by roasting, vaporizing and condensing. Most of the mercury in this country is used in the form of mercury compounds in blasting caps, for coloring red rubber products, and red oxide of mercury paint, while only a small amount goes into thermometers, barometers, and other laboratory apparatus.

Titanium is reduced by means of the Thermit process. Because it forms compounds with carbon, nitrogen, and silicon at high temperature, it is hard to make the metal in a free state. It finds use in the making of steel and as a white pigment in paint products.

The use of *gold* and *silver* in coins and jewelry needs little explaining. Gold is the standard of value and basis of the United States system of money because of its permanence and rarity. Most of the gold and silver presently produced is recovered as by-products of lead, zinc, and copper refining.

ADDITIONAL NON-FERROUS METALS

SHOP ____________________ NAME ________________________________

CLASS ____________________ INFORMATION SHEET NO. 3-7

QUESTIONS

1. Name the non-ferrous metals that cannot be used commercially in their pure state.
   a.
   b.
   c.

2. List a use for the following metals:
   a. Gold
   b. Titanium
   c. Mercury
   d. Vanadium
   e. Silver
   f. Tungsten
   g. Molybdenum

3. What metal is alloyed to make the material easier to forge?

4. Why has chromium replaced nickel in some instances for electroplating?

5. What metals are combined with bismuth to make a low-melting alloy?
   a.
   b.
   c.

Ask your instructor for Achievement Test No. 3 after you have completed the work in Unit III.

GENERAL PHYSICAL PROPERTIES

INDUSTRIAL MATERIALS

Strength of Materials – Machinists – Unit IV   Information Sheet No. 1

OBJECTIVE:

To acquaint the student with the general physical properties of industrial materials.

RELATED INFORMATION:

Let us see why industrial materials have come to play such a large part in man's daily life. Wood and stone, oldest in use, are being slowly replaced by other industrial materials. An example is the variety of exterior coverings for buildings that the builders are using.

Some of the reasons for this change in the use of materials may be seen in the greater strength, toughness, resistance to weather, and workability of the new products.

Metals, more than any of the other industrial materials, show many reasons for their greater use. Metals can be cast in varied shapes, forged, formed, welded, repaired, remelted, and used over again.

The selection of the proper industrial material for a given use is an important part of good design practice. For instance, strength, ease of shaping and low cost are of great importance for structural work. For these purposes, steel is best suited to satisfy the requirements. However, if corrosion resistance is required, non-ferrous alloys or plastic products would have to be used.

Where ease of machining is more important than strength,as is the case in the making of screws, the required industrial material could be steel or brass. If a casting does not require great strength, cast iron or cast brass can be used.

Steel which can be made soft or hard by heat treatment is used in the tool industry.

Metals light in weight for use in various ways are aluminum or magnesium and their alloys, while for softness and ease in bending, a necessity in the electrical and plumbing fields, lead, copper, plastics, and rubber find industrial uses.

Copper, aluminum and silver are the best conductors of electricity, with copper getting the greatest use because of its lower cost in giving a finished product.

Resistance to heat, electrical resistance, the melting point of a material, coefficient of expansion, and specific gravity must be taken into consideration when specifying an industrial material for practical use.

If all these properties, as outlined, are taken into consideration when you specify a material, the finished product should be well worth a place on the open market.

INDUSTRIAL MATERIALS

SHOP ____________________ NAME ____________________________________

CLASS ____________________ INFORMATION SHEET NO. 4-1

QUESTIONS

1. What are some of the reasons for the change in use of industrial materials?
    a.
    b.
    c.
    d.
    e.

2. Why are metals considered good materials to use in making products?
    a.
    b.
    c.
    d.
    e.
    f.
    g.

3. What must be taken into consideration in the design of industrial structures?
    a.
    b.
    c.

4. Why is copper used for electrical wiring?

5. Give the necessary requirements for materials in the electrical and piping industries.

    a.
    b.
    c.
    d.
    e.

GENERAL PHYSICAL PROPERTIES

STRENGTH

Strength of Materials – Machinists – Unit IV Job Sheet No. 1

OBJECTIVE:

To learn how various materials differ in strength.

WANTED:

Results of various tests.

MATERIALS:

Pieces of cast iron, wood, plastic, rubber, wrought iron, mild steel, brass, aluminum, hammer, vise.

PROCEDURE:

1. Strike each of the materials a blow with a hammer. Do the materials shatter, dent or withstand the blow of the hammer? Record your results.

2. Place your piece of material in the vise in such a manner that you can see if it will bend when you hit it on the side. Don't hit the material so hard that it will break.

GENERAL PHYSICAL PROPERTIES

HARDNESS

Strength of Materials – Machinists – Unit IV Job Sheet No. 2

OBJECTIVE:

To determine the hardness of various industrial materials.

WANTED:

Comparison of the hardness of the different industrial materials.

MATERIALS:

Pieces of cast iron, wood, plastic, rubber, wrought iron, mild steel, tool steel, brass, aluminum, Rockwell Hardness Tester.

PROCEDURE:

(To be done in machine shop)

1. The instructor will demonstrate how the Rockwell Hardness Tester is used to measure the hardness of the materials.

2. Record your results.

GENERAL PHYSICAL PROPERTIES

WEIGHT AND DENSITY

Strength of Materials – Machinists – Unit IV

Job Sheet No. 3

OBJECTIVE:

To learn that weight and density have an important bearing on the use of materials.

WANTED:

Reasons for using weight and density.

RELATED INFORMATION:

A major goal of product design in the competitive market is decreased size and weight and increased strength. You can read or see in the newspapers or trade magazines the many improvements in the overall size of objects. Not so many years ago, an automobile as we know it today was only a dream. The advances in the use of metal techniques has given us many structural advantages in the car you see in the showroom and on the street. Early airplanes were covered with a fabric material, yet only a few years after the invention of the plane, engineers were hard at work on an all-metal aircraft structure.

Weight and density, then, play an important part in the size and make-up of an object. Weight is a means of telling the difference between objects, while density of a material is its weight per unit volume. For example, one talks about the weight of an object in pounds (lbs.) or ounces (oz.) while the density is thought of and referred to in pounds per cubic inch (lbs./cu.in.) or pounds per cubic foot (lbs./cu.ft.).

The importance of knowing the weight of an object is realized in its use. The bulldozer operator likes the heavy equipment he is using because he knows he will get the job done. The pilot of an airplane feels secure in the knowledge that he has a craft that will fly under certain load conditions. The weight requirements have been figured by the engineering department after studies of many experiences. You will discover in your work experience that where weight has been ignored in the design of a machine, vibration or failure to perform the required work will be the result.

Density gives the machinist a quick reference to guide him in the weights of materials. Look at the tables in the Machinery's Handbook in the section listed in the table of contents as "Properties and Weights of Materials". Sheets, bars, rods, etc. are listed as a convenience in estimating weight. For example, if you needed to use a piece of steel ½" diameter and 12 inches long to make an adjusting screw shank, the weight of the material could be found by checking the table for weights of square and round steel bars which would be 0.850 lbs. You may think that weighing the piece would be easier and quicker, but sometimes a spring scale is not available.

The weight and density of materials are used to a great extent in estimating from blueprints. A customer submits a blueprint of an object to be made. Cost has to be figured for the machining time and the material. The densities of the various parts or the size and length can be found. With this information and using a reference book, the material weight can be found. Then, it is an easy matter to get the cost per pound of the material that has to be used. A complete bid can be submitted which will produce the article at a profit.

TOOLS AND MATERIALS:

½" diameter x 6" long bars of aluminum, brass, and steel, and spring balance or balance scale.

PROCEDURE:

1. Weigh each of the bars of metal.
2. Record the weights.
3. Check a reference table to see if your weights are in agreement.

WEIGHT AND DENSITY

SHOP ____________________ NAME ____________________________________

CLASS ____________________ JOB SHEET NO. 4-3

QUESTIONS

1. What is a major goal of product design?

2. Describe the difference between weight and density.

3. Give examples where weight in an object is important.

4. Could you estimate the weight of an object from a blueprint? Explain.

5. Find the weights of the following using a reference table:
    a. A piece of No. 24 copper sheet having an area of 1 sq. ft.

    b. $\frac{3''}{8}$ dia. x 12 in. long brass bar.

    c. Aluminum bar, 1" dia. x 6 in. long.

GENERAL PHYSICAL PROPERTIES

EXPANSION

Strength of Materials – Machinists – Unit IV   Job Sheet No. 4

OBJECTIVE:

To show that materials expand.

WANTED:

Cause of expansion of materials.

RELATED INFORMATION:

Did you ever notice and wonder why spaces were left between the concrete slabs on a highway? Or did you ever see a section of a highway buckle? The buckling was caused by too small an allowance of space between the slabs of concrete. As a result, on a hot day the concrete kept expanding until the only place it could go was up.

Be alert, when you work with materials, to the fact that they expand, otherwise you will run into trouble if you don't make allowance for the expansion.

MATERIALS:

Piece of polished steel ½ inch in diameter and six inches long, electric furnace, ring that just fits on steel rod.

PROCEDURE:

(This experiment should be conducted in the machine shop by the shop instructor).

1. Heat the bar until it becomes blue.
2. Show how the bar will not fit into ring.
3. Cool the bar.
4. Heat the ring and see if the bar can be inserted into it.

Ask your instructor for Achievement Test No. 4 after you have completed the work in this unit.

MECHANICAL PROPERTIES OF MATERIALS

ELASTICITY AND TOUGHNESS

Strength of Materials – Machinists – Unit V Job Sheet No. 1

OBJECTIVE:

To learn how the elasticity and toughness of a material are measured.

WANTED:

Method of measuring elasticity and toughness.

RELATED INFORMATION:

That stone is stronger than wood was common knowledge to our forefathers long before we began to set down rules as to the strength of materials. The need for speedier and economical development of materials led to demands for research and testing of these materials to prove their worthiness. The purpose of the testing laboratories is to check or to learn the strength and properties of materials. This procedure sets a standard whereby uniform material is obtained.

Two of the important properties of a material are its elasticity and its toughness.

Elasticity is the ability of a material to return to its original form after a load has been applied and removed.

Toughness is that ability of a material to undergo great change in shape or form under high stress before it breaks down.

If too heavy a load is applied to a material, it will not return to its original form. In this case, the *elastic limit* has been reached.

You, as a machinist, should know the limits of the materials in order to make the finished product sound in quality, economy, service, and performance.

TOOLS AND MATERIALS:

Various types of wire, measuring stick, micrometer, tension machine.

PROCEDURE: (Demonstration by the instructor).

1. Place the wire in the tension machine.

2. Measure the diameter and length of the wire. Record your measurements. Weight indicator should be at zero.

3. Turn handle ½ revolution. Record the weight, length and diameter of the wire.

4. Make several additional tests. Do not exceed the elastic limit. Follow procedure in Step 3.

5. Using the readings in Steps 2, 3, and 4, solve for the stretch modulus of elasticity (Young's Modulus) by the following formula:

Definition: *Total Deformation* equals the difference between the original length and the length with weight attached.

$$\text{Modulus of Elasticity (E)} = \frac{\text{Force (F)}}{\text{Cross-Sectional Area (A)}} \times \frac{\text{Length (L)}}{\text{Total Deformation (s)}}$$

You have learned a simple experiment in working out the elasticity and toughness of a material. In the laboratory, testing equipment is used to be sure the results are accurate. You have the background knowledge to prepare you to use the results that the laboratories have obtained on the various materials. Check in the Machinery Handbook to find the tables on Modulus of Elasticity.

ELASTICITY AND TOUGHNESS

SHOP ____________________ NAME ________________________________

CLASS ____________________ JOB SHEET NO. 5-1

PROBLEMS

A. 1. A steel bar, 48 inches long having a cross-sectional area of 1 square inch has a force of 12,000 lbs. pulling at its suspended end. If the force lengthens the bar 0.02 of an inch, what is the modulus of elasticity?

2. A wrought iron rod having a cross-sectional area of 2 square inches and 60 inches long stretches 0.001 inches when a load of 900 lb. is hung at the end of the rod. Find the modulus of elasticity for wrought iron. (Check your answer with the Machinery's Handbook).

3. An average cast iron bar is 2 square inches in cross-sectional area and is 32 inches long. What will the modulus of elasticity be if a load of 500 lbs. stretches the bar .0005 inches?

B 1. A carbon steel rod ½" x 1" and 6¼ feet long is stretched 0.015 inches when a load of 3000 lbs. is attached to it. What is the modulus of elasticity for the steel?

2. A piece of structural steel having a cross-sectional area of 3 square inches has a weight of 30,000 lbs. suspended from it. How much longer is it after the load is applied? (Hint: Look up modulus of elasticity for structural steel in the Machinery's Handbook and substitute in the formula).

C. 1. From experiments it is known that the modulus of elasticity for a certain type of steel is 29,000,000 pounds per square inch. What will be the total deformation in a strap, 1½ inches in diameter and 6½ feet long, when a stress of 6000 lbs. is applied to the rod?

MECHANICAL PROPERTIES OF MATERIALS

DUCTILITY AND HIGH TEMPERATURE STRENGTH

Strength of Materials – Machinists – Unit V Job Sheet No. 2

OBJECTIVE:

To learn what ductility in industrial materials means.

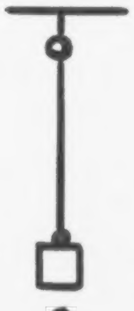
WANTED:

Difference in ductility of various industrial materials.

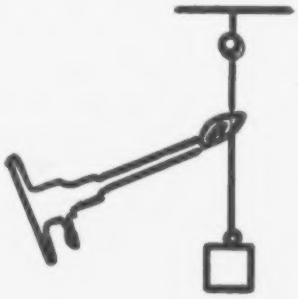
RELATED INFORMATION:

If a material resists rupture when greatly extended in tension, it is said to be *ductile*. Because of *ductility*, metal can be drawn into wire. To be formed in this manner, a metal must show good *tensile* strength after great deformation. Lead, for example, although easily deformed, cannot be drawn into wire because of its low tensile strength.

If heat is applied to most materials, it has been found that their strength decreases.



A



B

MATERIALS:

Steel and copper wire, weights, Bunsen burner or some other suitable heat.

PROCEDURE: (Demonstration by the instructor)

1. Keep adding weights to the steel wire as shown in Fig. A until the wire breaks. Record weights and size of wire.
2. Follow same procedure with the copper wire. Record results.
3. As you add weights to the steel wire, apply heat as shown in Fig. B. See if it takes less or more weight to break wire. Record results.

DUCTILITY AND HIGH TEMPERATURE STRENGTH

SHOP ____________________ NAME ________________________________

CLASS____________________ JOB SHEET NO. 5-2

QUESTIONS

1. What is meant by ductility?

2. Give five examples of ductile materials.
    a.
    b.
    c.
    d.
    e.

3. After great deformation, the metals must show what characteristic to be considered ductile?

4. What does heat do to strength of most material?

5. Give the order in which two metals tested in the experiment would be measured as to their ductility. (Percent of stretch and percent of reduction of their area).
    a.
    b.

MECHANICAL PROPERTIES OF MATERIALS

STIFFNESS

Strength of Materials – Machinists – Unit V Job Sheet No. 3

OBJECTIVE:

To learn why stiffness of materials is often necessary.

RELATED INFORMATION:

Stiffness is that property of a material whereby it can support a large load without losing its shape.

Look at the machines in your shop or the tables and chairs in the science room. If they were not provided with proper support, either a shaking action or buckling might result.

The knowledge that the lathe center, tool bits, broaching bar, etc. are examples of materials requiring stiffness as one means of performing work should help you in trade as a machinist.

MATERIALS:

Two steel rods of different diameters, compression machine.

PROCEDURE: (Demonstration by the instructor)

1. Insert the small-diameter steel rod into the compression machine.
2. Apply pressure. Does the rod bend?
3. Try the same procedure with the larger diameter rod in the same material. What happens?

STIFFNESS

SHOP ____________________ NAME ____________________________________

CLASS ____________________ JOB SHEET NO. 5-3

QUESTIONS

1. What is stiffness?

2. Give five examples of stiffness as it is applied to the machines in the shop.
    a.
    b.
    c.
    d.
    e.

3. The legs on the stools at the work benches are made of angle iron. Explain the reason for using this material instead of flat rectangular or square stock.

4. Explain why a small drill in a drill press buckles when fed into the work too rapidly and with too much pressure.

MECHANICAL PROPERTIES OF MATERIALS

HARDNESS

Strength of Materials – Machinists – Unit V — Job Sheet No. 4

OBJECTIVE:

To learn how different materials have varying hardnesses.

WANTED:

Hardness values of some materials.

RELATED INFORMATION:

Hardness is the resistance that a substance offers to the separation of its particles by the penetrating action of another substance.

TOOLS AND MATERIALS:

Rockwell Hardness Tester, pieces of cast iron, cold-rolled steel, hot-rolled steel, tool steel, brass.

PROCEDURE: (test demonstration to be done by machine shop instructor)

1. Test each piece of metal in the Rockwell Hardness Tester.

2. Record results of the tests.

3. List the different metals in the order of their hardness.

HARDNESS

SHOP ____________________ NAME ____________________________________

CLASS ____________________ JOB SHEET NO. 5-4

QUESTIONS

1. What is material hardness?

2. Why is the tool steel harder than the brass?

3. Give two reasons for using the Rockwell Hardness Tester.

   a.

   b.

MECHANICAL PROPERTIES OF MATERIALS

MALLEABILITY

Strength of Materials – Machinists – Unit V   Job Sheet No. 5

OBJECTIVE:

To learn if materials have malleability.

WANTED:

Comparison of materials as to their malleability.

RELATED INFORMATION:

A material is malleable when it can be rolled or hammered into sheets without breaking or cracking. Looking at the order of malleability of various metals listed below, you will find gold is the most malleable material.

ORDER OF MALLEABILITY

1. Gold
2. Silver
3. Aluminum
4. Copper
5. Tin
6. Lead
7. Zinc
8. Platinum
9. Iron

Many people have the idea that a malleable material gets its shape by the compression of the particles that go into its make-up. Actually, the particles slide over one another as the sheet gets longer and thinner.

TOOLS AND MATERIALS:

Furnace, samples of mild steel, tool steel, wrought iron, vise, hammer.

PROCEDURE:

1. Heat sample of mild steel.

2. Make a rough test for malleability.

3. Follow same procedures for tool steel and wrought iron.

MALLEABILITY

SHOP ____________________ NAME ______________________ ________

CLASS ____________________ JOB SHEET NO. 5-5

QUESTIONS .

1. List metals in order of their malleability.
   a.
   b.
   c.
   d.
   e.
   f.
   g.
   h.
   i.

2. What is a malleable material?

3. Explain the action in a malleable material.

4. Which is more malleable, copper or wrought iron?

MECHANICAL PROPERTIES OF MATERIALS

RESILIENCE AND IMPACT STRENGTH

Strength of Materials – Machinists – Unit V Job Sheet No. 6

OBJECTIVE:

To learn how materials are resistant to impact.

WANTED:

Comparison of materials as to their impact strength.

RELATED INFORMATION:

You have experimented in seeing how a hammer striking a section of rubber rebounded many times without any visible effect on an object. The ability of the rubber to store the energy and resist the *impact* (suddenly applied load) of the hammer head resulted from its *resilience*. You may have had the unfortunate experience of striking cast iron and found after it broke that it was not resilient.

The toughness of the receiving body in terms of its ability to take the work-energy of the blow or falling weight is called its *impact strength*. Would you say rubber or cast iron had greater impact strength?

TOOLS AND MATERIALS:

Izod Impact Apparatus, pieces of cast iron, steel, copper and aluminum.

PROCEDURE: (Demonstration by the instructor)

1. Put a sample of a metal in the vise of the apparatus.

2. Strike the metal a blow.

3. Record result.

4. Follow the same procedure for the other metals.

RESILIENCE AND IMPACT STRENGTH

SHOP ____________________ NAME __________________________________

CLASS ___________________ JOB SHEET NO. 5-6

QUESTIONS

1. What is meant by resilience?

2. Define impact strength.

3. Show the order of toughness of the materials used in the experiment.

4. Would the impact strength be higher if the copper and aluminum were hardened? Why?

MECHANICAL PROPERTIES OF MATERIALS

CORROSION RESISTANCE

Strength of materials – Machinists – Unit V Job Sheet No. 7

OBJECTIVE:

To see how materials stand up under corrosion.

WANTED:

Conclusions on corrosion resistance of materials.

RELATED INFORMATION:

There are three classes of compounds that have a bearing on the reaction of metals. They are acids, bases, and salts.

An acid turns blue litmus paper red, is sour in taste and forms a soluble salt of the metal in reactions with metals.

A base can be identified by the fact that its characteristics turn red litmus blue, feels soapy and slippery to the touch and has a bitter metallic taste.

Salts are the compounds that results when an acid neutralizes a base.

For example, the reaction of lye or caustic soda (base) plus hydrochloric acid produces table salt and water.

You learned how to identify iron and steel by spark tests. Chemical tests in the form of corrosive actions can be used for the same purpose. The chemical action may be in one spot or the material could be immersed. The spot test is usually preferred because the object cannot be destroyed.

MATERIALS:

Carbon steel, aluminum, magnesium, lead, tin-plated container, copper, stainless steel, monel, hydrochloric acid, sulphuric acid, nitric acid, copper sulphate, silver nitrate, acetic acid.

PROCEDURE:

(To be demonstrated by instructor. Follow good safety practices in the handling of chemicals and materials).

1. Test aluminum and magnesium with drop of silver nitrate.

2. Show effect of drop of acetic acid, hydrochloric acid and sulphuric acid on aluminum, lead, copper, carbon steel and tin-plated container.

3. What happens when a drop of copper sulphate is placed on carbon steel?

4. Put a drop of hydrochloric and nitric acids on test strips of stainless steel and monel metals.

CORROSION RESISTANCE

SHOP ____________________ NAME ________________________________

CLASS ____________________ JOB SHEET NO. 5-7

QUESTION

1. State spot tests for identifying the following metals:

   a. Aluminum

   b. Magnesium

   c. Carbon steel

   d. Lead

   e. Copper

   f. Tin

   g. Stainless steel

   h. Monel

Ask your instructor for Achievement Test No. 5 after you have completed this unit.

THE PLAIN CARBON STEEL

CARBON STEEL STRUCTURE

OBJECTIVE:

To learn the structure of normal steel and effects of heat treatment.

WANTED:

The importance of the rate of cooling the work.

RELATED INFORMATION:

All steels contain carbon, which determines its properties and uses. Plain carbon steels have no alloying elements such as nickel, tungsten, etc.

The effect of carbon upon steel depends upon the amount of carbon, size and shape of the carbon-steel particles, and the manner in which the particles place themselves in the crystal state.

The process of controlled heating and cooling is known as the heat treatment of steel.

Take for example a baked potato. If you were to look into a cook book, the directions for preparation, the heat of the oven and the length of time before it is ready to eat would be there. While quite a bit of information is given on a blueprint for the hardening of an object, the Machinery's Handbook helps you with heat-treating directions.

With the importance of selecting the right materials becoming a daily requirement of the engineering department, the application of these materials and processes should be known by the machinist if he is to do a good job.

TOOLS AND MATERIALS:

Furnace, water quench, Rockwell Hardness Tester, number stamps, ball peen hammer, emery cloth, four peices of medium carbon steel.

PROCEDURE: (To be demonstrated by machine shop instructor)

1. Number sample pieces 0, 1, 2, 3.
2. Check hardness of each on Rockwell. Set aside piece No. 0 as a means of checking original hardness.

3. Place piece No. 1 in furnace which has a temperature of 1250° F. Remove rapidly after recording time and quench until completely cooled.

4. Follow same procedure with piece No. 2 except to raise furnace temperature to 1350° F.

5. Follow same procedure as step 3 with piece No. 3 except to raise furnace temperature to 1500° F.

6. Prepare each piece for the hardness tester by cleaning samples with emery cloth.

7. Record the results.

CARBON STEEL STRUCTURE

SHOP ____________________ NAME ________________________________ __

CLASS ____________________ JOB SHEET NO. 6-1

QUESTIONS

1. List the samples in the order of their hardness.

   a.

   b.

   c.

   d.

2. What do all steels contain?

3. Explain what is meant by the heat treatment of steel.

4. The effect of the carbon in the steel depends upon:

   a.

   b.

   c.

THE PLAIN CARBON STEELS

CARBON CONTENT

Strength of Materials – Machinists – Unit VI Information Sheet No. 1

OBJECTIVE:

To learn the carbon content of steel and uses for each classification.

RELATED INFORMATION:

The carbon content of steel may vary from a few hundredths of one percent to 1.40% carbon.

The chart shown below will help you identify uses for the various grades of steel:

Carbon Range Percent	USES OF CARBON STEEL
0.05-0.12	Chain, stampings, rivets, nails, wire, pipe, welding stock, where very soft plastic steel is needed.
0.10-0.20	Very soft, tough steel. Structural steels, machine parts. For case-hardened machine parts, screws.
0.20-0.30	Better grade of machine and structural steel. Gears, shafting, bars, bases, levers, etc.
0.30-0.40	Responds to heat treatment. Connecting rods, shafting, crane hooks, machine parts, axles.
0.40-0.50	Crankshafts, gears, axles, shafts, and heat-treated machine parts.
0.60-0.70	Low-carbon tool steel, used where a keen edge is not necessary, but where shock strength is wanted. Drop-hammer dies, set screws, locomotive tires, screw drivers.
0.80-0.90	Punches for metal, rock drills, shear blades, cold chisels, rivet sets, and many hand tools.
0.90-1.00	Used for hardness and high tensile strength, springs, high tensile wire, knives, axes, dies for all purposes.

Carbon Range Percent	USES OF CARBON STEEL
1.00-1.10	Drills, taps, milling cutters, knives, etc.
1.10-1.20	Used for all tools where hardness is prime consideration; for example, ball bearings, cold cutting dies, drills, wood-working tools, lathe tools, etc.
1.20-1.30	Files, reamers, knives, tools for cutting brass and wood.
1.25-1.40	Used where a keen cutting edge is necessary; razors, saws, instruments, and machine parts where maximum resistance to wear is needed. Boring and finishing tools.
0.25-0.65	Forgings, castings.

CARBON CONTENT

SHOP ____________________ NAME ____________________________________

CLASS ____________________ INFORMATION SHEET NO. 6-1

PROBLEM

Match column B with Column A.

		(A) CARBON RANGE %		(B) USES
________	a.	0.60-0.70	1.	Files
________	b.	1.25-1.40	2.	Punches
________	c.	0.10-0.20	3.	Crankshafts
________	d.	0.80-0.90	4.	Rivets
________	e.	1.10-1.20	5.	Levers
________	f.	0.05-0.12	6.	Razors
________	g.	0.25-0.65	7.	Taps
________	h.	0.40-0.50	8.	Machine parts
________	i.	1.20-1.30	9.	Structural steels
________	j.	0.90-1.00	10.	Screwdrivers
			11.	Anvil faces
			12.	Springs
			13.	Lathe tools
			14.	Castings

THE PLAIN CARBON STEELS

CLASSIFICATION

Strength of Materials – Machinists – Unit VI Information Sheet No. 2

OBJECTIVE:

To learn how carbon steels are classified.

RELATED INFORMATION:

The need for standard specifications was shown as the demand for better grades increased. With the many types of steel being called for, the steel makers and societies put together sheets classifying the steels according to their standard specification for easier selection by the consumer.

Since the majority of the steel handbooks refer to the S.A.E. and the comparable AISI standards, only these specifications will be explained. Although the specifications were supposed to be used by the automobile industry, they have found their way into all industries where steels are being used. In the section of the Machinery Handbook, SAE Standard Steels, you will find the compositions, applications, and heat-treatments of the various steels. Use of the section will be helpful in the selection of the proper type of steel for the job you want it to do.

The SAE and AISI compositions of steel are identified by a numbering system. The difference in the numbering is that a letter A, B, C, D, Q, or R is placed in front of the AISI numbers, the letters being used to identify the steel furnace process as follows:

A – Basic openhearth alloy steel
B – Acid bessemer carbon steel
C – Basic openhearth carbon steel
D – Acid openhearth carbon steel
Q – Forging or special requirement quality
R – Re-rolling quality

If you look at the chart below, you will find the first digit or number shows the type of steel; the second number shows the approximate percentage of the alloying element; and the remaining numbers, the average carbon content.

(For example, an SAE-numbered steel 1010 would be broken down as follows: The 1 would indicate a plain carbon steel, the 0 shows no alloy, and the 10 means approximately .10% carbon in the composition).

BASIC SAE NUMBERING SYSTEM FOR STEELS

TYPE OF STEEL	SAE NUMERALS
CARBON STEELS	1xxx
Plain carbon	10xx
Free cutting (screw stock)	11xx
High manganese	13xx
NICKEL STEELS	2xxx
3.50% nickel	23xx
5.00% nickel	25xx
NICKEL CHROMIUM STEELS	3xxx
1.25% nickel, 0.60% chromium	31xx
3.50% nickel, 1.50% chromium	33xx
MOLYBDENUM STEELS (0.25% molybdenum)	4xxx
Chromium (1.0%)	41xx
Chromium (0.5%), nickel (1.8%)	43xx
Nickel (2%)	46xx
Nickel (3.5%)	48xx
CHROMIUM STEELS	5xxx
Low Chrome	51xx
Medium Chrome	52xx
CHROMIUM VANADIUM STEELS	6xxx
NICKEL – CHROMIUM – MOLYBDENUM (Low amounts)	8xxx
SILICON – MANGANESE	92xx

CLASSIFICATION

SHOP ____________________ NAME ____________________________________

CLASS ____________________ INFORMATION SHEET NO. 6-2

PROBLEMS

1. Give the specifications of the following:
    - a. 1095
    - b. C1070
    - c. 1020
    - d. C1052
    - e. 1027

2. Write the following specifications into SAE or AISI numbers:
    - a. Plain carbon steel having .41% carbon.
    - b. An .85% plain carbon steel.
    - c. A plain carbon steel with .06% carbon.

3. Which type of furnace is used to make the steels of the following compositions?
    - a. C1090
    - b. 1035

Ask your instructor for Achievement Test No. 6 after you complete the work in this unit.

THE CONTROL OF PHYSICAL PROPERTIES OF METALS

HEAT-TREATING OF STEEL

Strength of Materials – Machinists – Unit VII Job Sheet No. 1

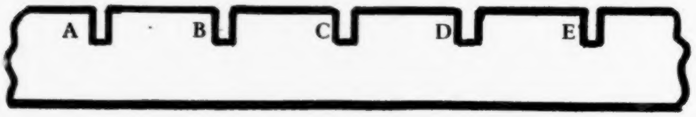
OBJECTIVE:

To learn how the physical properties of steel are controlled by heat treating.

WANTED:

Comparison of hardness of a high-carbon steel with the quenching rate in air, oil, water and brine (room temperature).

SKETCH:



MACHINED TEST PIECE

RELATED INFORMATION:

As you have learned, heat treating is the process of controlled heating and cooling. Steel is an important product because it can be heat-treated for use in a variety of ways. You will learn how quenching, tempering, normalizing, annealing and surface treatment make steel ready for a particular use.

TOOLS AND MATERIALS:

Furnace, water quench, grinder, machined test peice, Rockwell Hardness Tester, hammer.

PROCEDURE: (To be done in the machine shop)

1. Heat furnace to 1900° F. to 2000° F. Maintain furnace at this temperature.
2. Place test piece in furnace so that one end will be in hottest zone and the other end sticks out of the furnace.
3. When the hot end of the bar shows no dark shadow and the cold end has remained black, remove quickly and quench in water.
4. Break bar into five pieces with a sharp blow of a hammer.
5. Grind off decarburized surface about 0.01–0.02 inch deep. (Avoid heating piece by using coolant. Don't remove number).
6. Measure hardness of various pieces with Rockwell Hardness Tester.
7. Examine crystal structure at each broken section.
8. Record results.

HEAT-TREATING OF STEEL

SHOP ____________________ NAME ________________________________

CLASS ____________________ JOB SHEET NO. 7-1

QUESTIONS

1. How do you know that a piece is completely heated?

2. Why is it important to remove test piece from furnace and put in the water quench quickly?

3. Can you explain why there was a difference in hardness in the various pieces of the test piece?

4. What is the fastest coolant used commercially for metals?

5. What happens when a piece of metal is heated? (one word)

6. Why is steel heat-treated?

7. What is heat-treatment?

8. Describe the crystal structure of the pieces of steel used in the experiment.

THE CONTROL OF PHYSICAL PROPERTIES OF METALS

WARPING AND CRACKING

Strength of Materials – Machinists – Unit VII　　Job Sheet No. 2

OBJECTIVE:

To learn how steels warp and crack in heat treating.

WANTED:

Reasons for warping and cracking of steel.

RELATED INFORMATION:

The hardening of steel is a skill that has to be mastered. It takes practice to get a fully hardened piece without warpage or cracking when quenching is involved.

Several reasons can be given for warping and cracking of steel. They are the difference in cooling of thick and thin sections, the composition of the steel and the critical cooling rate (minimum rate of cooling to give full hardening) of steel.

The use of fixtures is one means of keeping fast-cooling thin sections from warping or cracking because of their faster contracting rate. If you know the composition and rate of cooling of the steel you are working with and if you follow heat-treating directions, you will eliminate a danger in the area of the steel's make-up.

TOOLS AND MATERIALS:

Furnace, quenching baths of oil and water, Rockwell Hardness Tester, two pieces of high-carbon steel, two pieces of oil hardening high-carbon tool steel, stamp set, ball-peen hammer.

PROCEDURE: (To be done by machine shop instructor)

1. Stamp the carbon-steel pieces 1A and 1B and the tool-steel pieces 2A and 2B.

2. Test pieces in Rockwell Tester.

3. Place the four pieces in the oven and raise the temperature to 1450° F. Let samples remain in the furnace until thoroughly heated.

4. Quickly remove pieces marked A and quench in water, and quickly remove pieces marked B and quench in oil until vibration ceases.

5. Remove pieces from quench tank and place in tempering tank at 450° F. for about 30 minutes.

6. After removal from tempering tank, quench, clean and examine specimens.

7. Test pieces for hardness with Rockwell Tester.

WARPING AND CRACKING

SHOP ____________________ NAME ______________________________

CLASS ____________________ JOB SHEET NO. 7-2

QUESTIONS

1. Name several reasons for warping or cracking.

   a.

   b.

   c.

2. How are thick-and thin-sectioned materials kept from warping after heat treating?

3. Why was oil used as a cooling bath?

4. Did any of the pieces crack or warp in the experiment? Why?

5. Give the Rockwell hardness for the various pieces before and after heat treating.

	1A	1B	2A	2B
Before				
After				

THE CONTROL OF PHYSICAL PROPERTIES OF METALS

HEAT TREATING PROCESSES

Strength of Materials – Machinists – Unit VII   Job Sheet No. 3

OBJECTIVE:

To learn how to heat-treat steel for specific applications.

RELATED INFORMATION:

As has been explained in previous lessons, the properties of steel can be changed by heating and cooling. Heat-treating, then, is a process of making a steel more suited for specific applications.

Several methods are used depending upon their needs. For instance, when a hard, wear-resisting surface is needed, case-hardening, a process of changing the outer layer of mild steel into tool steel, is used. Other methods that will be demonstrated for you are tempering (making hardened steel suitable as a cutting tool), annealing (putting steel into shape for easy machining), normalizing (improving of grain structure of otherwise poor steel), nitriding (surfacing hardening of special alloy steels), and cyaniding (surface hardening of small parts made from low-carbon steel).

TOOLS AND MATERIALS:

For case-hardening, tempering, annealing, normalizing, nitriding and cyaniding, see Metals Technology – Delmar.

PROCEDURE: (To be done in the machine shop)

Demonstrate the following heat-treating processes:

a. Case-hardening
b. Tempering
c. Annealing
d. Normalizing
e. Nitriding
f. Cyaniding

HEAT TREATING PROCESSES

SHOP ______________________ NAME ______________________________________

CLASS ______________________ JOB SHEET NO. 7-3

QUESTIONS

1. Why is a hard case given to steel?

2. Why was the work held in the furnace for such a long time?

3. Fill in the information for the chart listed below from the tempering demonstration:

Specimen	Rockwell Before Hardening	Hardness After Hardening	Tempering Furnace Temperature	Rockwell No. After Tempering
1.			400°F	
2.			600°F	
3.			800°F	
4.			900°F	
5.			1000°F	
6.			1100°F	
7.			1200°F	

4. What is the main purpose of annealing?

5. What is normalizing?

6. Is the term normalizing applied to non-ferrous materials?

7. What has to be done to cold-rolled steel before surface machining? Why?

8. What gas is used for nitriding?

9. What limits the use of the nitriding process?

10. What is cyaniding?

THE CONTROL OF PHYSICAL PROPERTIES OF METALS

SURFACE TREATMENTS

Strength of Materials – Machinists – Unit VII   Information Sheet No. 1

OBJECTIVE:

To learn the various surface treatments and why they are used.

RELATED INFORMATION:

A thin layer of metal coated to the outer surfaces of a piece of steel may give it greater resistance to corrosion or greater sales appeal.

One of the most common methods of plating surfaces that you may know is the dipping of steel into molten baths of tin or zinc to form tin plate or zinc-galvanized sheets.

Other methods of plating steel are the Schoop metallizing process (spray of atomized molten metal is directed on to the surfaces of heated metal objects); Parkerizing (iron phosphate coating on steel by dipping in a hot solution of manganese dihydrogen phosphate); Bonderizing (thin, phosphate coating needing a paint spray for complete protection); Surface Oxidation (bluing or blacking of steel); Metal Spray Process (fused powdered metal is sprayed from gun and deposited on the surface to be coated).

A table showing the coated metal and its use follows:

COATED METAL	USE
Tin plate	Canning industry
Zinc galvanizing	Sheet metal work
Parkerizing	Hardening surfaces of iron and steel
Bonderizing	Resisting wear on pistons, piston rings, camshafts, etc.
Surface oxidation	Gun parts, small tools, spark plug parts, etc.
Metal spray process	Building up of work parts of machines, such as shafts, cylinders, rolls, etc.

SURFACE TREATMENTS

SHOP ____________________ NAME ____________________________________

CLASS ____________________ INFORMATION SHEET NO. 7-1

QUESTIONS

1. What does a coating of a thin layer of metal do to steel?

2. Where is tin plate used?

3. What does Parkerizing do to iron or steel?

4. How are worn parts of machines built up?

5. What is Bonderizing?

6. Where is Bonderizing used?

7. Name the most common method of dipping steel.

8. Where is surface oxidation used?

9. Explain the Schoop metallizing process.

10. Where are zinc galvanized sheets used?

THE CONTROL OF PHYSICAL PROPERTIES OF METALS

HEAT TREATING OF NON-FERROUS METALS

Strength of Materials – Machinists – Unit VII | Job Sheet No. 4

OBJECTIVE:

To learn why non-ferrous metals are subjected to heat treatment and some uses for each.

WANTED:

To compare hardnesses of a copper-base alloy before and after hardening.

RELATED INFORMATION:

Non-ferrous metals, both pure and as alloys, have many applications. The properties of these metals can be altered by heat-treating to meet exacting requirements.

Pure aluminum 25 and wrought-aluminum alloys are annealed by heating and cooling to allow the strain-hardened crystal state of the aluminum to revert to its original soft metal.

Several of the aluminum alloys may have their hardness increased by a solution heat treatment. In this process, the alloy is heated for a long period of time (about 14 hours), then cooled very rapidly by quenching in water.

If the solution heat treated alloy is allowed to cool at room temperature, the alloy seems to increase in strength after 30 minutes. This reaction is known as precipitation hardening. Some compositions of aluminum alloys that respond to heat treatment do not develop any increase in strength when allowed to cool in this manner. However, heating these alloys to slightly above room temperature allows precipitation to take place.

Cast and forged alloys of the aluminum family can take heat-treating to improve their properties. The casting alloys require longer soaking periods in solution heat treating to change the structure and properties.

Magnesium-aluminum alloy castings develop their maximum properties only upon proper heat treatment.

Annealing is the only method of heat treatment used on pure copper or brass, while other heat treatments are used with some of the copper alloys. The annealed copper and brass present a ductile and soft metal in comparison with the improved hardness and other properties of the alloys.

With proper heat treatments, hardness-values of Rockwell C54 and higher can be obtained with copper-manganese-nickel alloys.

Listed on the following page are the heat-treated metals and their uses.

HEAT TREATED METAL OR ALLOY	USF
25 Aluminum	Cooking utensils, sheet metal work
Wrought-aluminum alloys	Rivets, rolled forms
Magnesium – aluminum castings	Household applicances, aircraft gears and engines, automobile industry
Copper	Ornamental and sheet metal work
Brasses	Forgings, shells, lighting fixtures
Bronzes	Springs, bearings, condenser tubes
Copper-manganese-nickel alloys	Non-sparking hand tools

TOOLS AND MATERIALS:

Furnace, stamp set, ball-peen hammer, Rockwell Hardness Tester, eight samples of a copper-base alloy, quenching bath.

PROCEDURE: (To be done in the machine shop)

1. Stamp each slug 0, 1, 2, 3, 4, 5, 6, 7.
2. Rockwell-test each piece and record results.
3. Place all pieces except 0 in furnace.
4. Raise furnace temperature to 215° F. for ¼ hour. Remove piece No. 1 and quench.
5. Remove piece No. 2 after ¼ hour and having raised temperature to 400° F. Quench.
6. Follow same procedure as furnace temperature is raised from 400° F. to 550°F., to 650° F., to 850°F., to 1000° F., and to 1200° F. Remember to remove and quench samples 3, 4, 5, 6, 7 in that order at each furnace change.
7. Measure hardness of each piece. Record results.

HEAT TREATING OF NON-FERROUS METALS

SHOP ____________________ NAME ____________________________________

CLASS ____________________ Job Sheet No. 7-4

QUESTIONS

1. How can properties of non-ferrous metals be altered to meet exacting requirements of various applications?

2. State the proper heat-treating method for the following;

   a. Brass

   b. Aluminum alloys

   c. Copper

3. Complete the chart listed below:

Piece	Hardness Before Heating	Hardness After Heating
0		
1		
2		
3		
4		
5		
6		
7		

Ask your instructor for Achievement Test No. 7 after you complete the work in this unit.

THE ALLOY STEELS

DEFINITION AND TYPES

Strength of Materials – Machinists – Unit VIII   Information Sheet No. 1

OBJECTIVE:

To learn what is meant by alloy steels.

RELATED INFORMATION:

All steels are alloy steels when you consider that they contain at least two elements, iron and carbon. The term alloy, as it is used in the industrial world, is applied to those steels containing at least one other element besides iron and carbon. The quality of the steel is made according to the proportions called for in the specifications set up by the different steel societies.
(SAE – Society of Automotive Engineers; ASTM – American Society of Testing Materials; AISI – American Iron and Steel Institute).

The principal alloying elements that combine with steel are nickel, chromium, manganese, tungsten, molybdenum, vanadium, and silicon. Often, two or more are required to give the steel the desired grade for use in construction. Therefore, if you hear a steel labelled ternary (three major elements) or quarternary (four major elements), you know that in the former case it may be nickel steel or the latter, chromium-vanadium steel. Also, the name given the alloy is taken from the main alloying element, such as when nickel is added to iron and carbon, it is called nickel steel.

With the demand for high-grade steels in recent years, research work and maintenance of specifications by the steel manufacturers have been of prime importance. Where years ago the yardstick for measuring a good steel was how well a metal could withstand hard use, today the large steel plant has specially equipped laboratories for testing and improving steel materials.

By alloying elements, two effects on steel are noticed. They are:

1. Addition of third element to iron and carbon can result in a change in its properties.

2. Alloying elements may necessitate great changes in heat-treatment.

With the addition of small amounts of other elements, iron and carbon have come a long way from the stage where heat-treating was the only method of improving steel.

Know your steels and use them wisely if you want to become tomorrow's better informed machinist.

DEFINITION AND TYPES

SHOP ____________________ NAME ____________________________________

CLASS ____________________ INFORMATION SHEET NO. 8-1

QUESTIONS

1. What is an alloy steel?
2. Who has set up the steel qualifications or specifications?
3. Name some of the principal alloying elements that combine with iron and carbon.
4. Identify each of the following alloys as ternary or quaternary steels:
    a. Vanadium steel
    b. Nickel steel
    c. Silico-manganese steel
    d. Tungsten steel
    e. Nickel-chromium steel
5. What was the yardstick, years ago, for measuring a good steel?
6. How different is the present practice of judging a good steel? Explain.
7. What two effects are produced by the alloying of steels?
8. How do the alloys get their names?

THE ALLOY STEELS

CLASSIFICATION

Strength of Materials – Machinists – Unit VIII   Information Sheet No. 2

OBJECTIVE:

To learn how alloyed steels are classified.

RELATED INFORMATION:

As you have learned in a previous unit, the need for standard types of alloys was brought about by demand. The steel makers and societies put together data sheets specifying the exact composition of the steel alloy. This procedure gave the machinist or engineering department an easier selection of the material required to do the job.

If you look at the chart that follows, you will find the first digit or number shows the type of steel; the second number gives the approximate percentage of alloying metal, and the remaining numbers give the average carbon content. (For example, an AISI-numbered steel 5140 would be broken down as follows: The 5 would indicate a chromium steel, the 1 shows approximately 1% of chromium, and the 40 means an average of .40% carbon in the composition).

The section on SAE Standard Steels in a Machinery's Handbook will give you the compositions, applications, and heat-treatments of the various steels.

TYPE OF STEEL	NUMERALS *
Carbon Steels	1xxx
Plain Carbon	10xx
Free Cutting, (Screw Stock)	11xx
Manganese Steels	13xx
Nickel Steels	2xxx
3.50% Nickel	23xx
5.00% Nickel	25xx
Nickel-Chromium Steels	3xxx
1.25% Nickel, .60% Chromium	31xx
1.75% Nickel, 1.00% Chromium	32xx
3.50% Nickel, 1.50% Chromium	33xx
Corrosion-and Heat-Resisting Steels	30xxx
Molybdenum Steels	4xxx
Carbon-Molybdenum	40xx
Chromium-Molybdenum	41xx
Chromium-Nickel-Molybdenum	43xx
Nickel-Molybdenum	46xx and 48xx
Chromium Steels	5xxx
Low Chromium	51xx
Medium Chromium	52xx
Corrosion-and Heat-Resisting	51xxx
Chromium-Vanadium Steels	6xxx
1% Chromium	61xx
Silicon-Manganese Steels	9xxx
2% Silicon	92xx

* The x quantity or digit would be governed by the specification. For example, a nickel steel having approximately 3% nickel and .40% carbon would be indicated 2340.

CLASSIFICATION

SHOP ____________________ NAME ____________________________________

CLASS ____________________ INFORMATION SHEET NO 8-2

PROBLEMS

1. Write the following specifications into SAE numbers:

   a. Manganese Steel having approximately 20% Carbon.

   b. Nickel Steel having approximately 5% Nickel and .15% Carbon.

   c. Molybdenum Steel having approximately 1% Chromium, and .30% Carbon.

2. Give the approximate composition of the following SAE steels:
   a. 5150

   b. 3115

   c. 1340

3. Indicate the furnace process and composition of the following AISI steels:
   a. E3310

   b. C1010

   c. B1111

THE ALLOY STEELS

COLOR CODE

Strength of Materials – Machinists – Unit VIII Information Sheet No. 3

OBJECTIVE:

To learn how steel is coded by color.

RELATED INFORMATION:

If you were to use a great amount of time trying to identify a piece of steel, the resulting product would be priced too high for the market. To overcome this difficulty and to help you to identify a particular steel quickly, a *Steel Color Code* was devised by the National Association of Purchasing Agents using the SAE steel classification.

The method of marking bars varies according to the steel. The straight carbon steels are painted a plain solid color on each end of the bar while the alloy steels have a solid color identifying the alloy plus a stripe or dot giving the average carbon content. (For example, looking at the chart that follows, SAE 1040 plain carbon steel would be recognized by the dark red color on the bar ends).

Color Code for SAE Carbon Steels

SAE NO.	Solid Color	Stripe Color	SAE NO.	Solid Color	Stripe Color
1010	Yellow	None	1045	Lead	None
1015	Light Blue	None	1046	Orange	None
1020	Dark Blue	None	1050	Brown	None
1025	Light Green	None	1095	Tan	None
1030	Dark Green	None	1350	Red	Tan
1035	Light Red	None	1360	Orange	Tan
1040	Dark Red	None	1112	White	None
			1120	Black	None

Color Code for SAE Nickel Steels

SAE NO.	Solid Color	Stripe Color	SAE NO.	Solid Color	Stripe Color
2315	Natural	Red	2340	Red	White
2320	Red	Blue	2345	Red	Brown
2325	Red	Green	2350	Red	Black
2330	Red	Lead	2512	Lead	Red
2335	Red	Orange			

Color Code for SAE Chrome Nickel Steels

(*The asterisk indicates *dot* instead of *stripe.*)

SAE NO.	Solid Color	Stripe Color	SAE NO.	Solid Color	Stripe Color
3115	White	Red	3315	Black	Red
3120	White	Blue	3320	Black	Blue
3125	White	Green	3325	Black	Green
3130	White	Lead	3330	Black	Lead
3135	White	Orange	3335	Black	Orange
3140	White	Black	3340	Black	White
3312	Black	*Red	3350	Black	Yellow

Color Code for SAE Molybdenum Steels

SAE NO.	Solid Color	Stripe Color	SAE NO.	Solid Color	Stripe Color
4130	Green	Lead	4150	Green	Black
4140	Green	White	4615	Green	Red

Color Code for SAE Chromium Steels

(*The asterisk indicates *dot* instead of *stripe.*)

SAE NO.	Solid Color	Stripe Color	SAE NO.	Solid Color	Stripe Color
5120	Yellow	Blue	5165	Yellow	Red
5140	Yellow	White	5195	Yellow	Green*
5150	Yellow	Black	5210	Yellow	Brown*

Color Code for SAE Chrome Vanadium Steels

SAE NO.	Solid Color	Stripe Color	SAE NO.	Solid Color	Stripe Color
6120	Dark Blue	Red	6140	Dark Blue	White
6125	Dark Blue	Green	6145	Dark Blue	Brown
6130	Dark Blue	Lead	6150	Dark Blue	Black
6135	Dark Blue	Orange	6195	Dark Blue	Yellow

Color Code for Silicon Manganese

SAE NO.	Solid Color	Stripe Color	SAE NO.	Solid Color	Stripe Color
9250	Light Blue	Black	9260	Light Blue	Yellow

COLOR CODE

SHOP ____________________ NAME ____________________________________

CLASS ____________________

INFORMATION SHEET 8-3

PROBLEM

Give the correct color code marking for the following:

1. SAE 1010
2. SAE 1360
3. SAE 2335
4. SAE 3115
5. SAE 3350
6. SAE 4140
7. SAE 5150
8. SAE 5195
9. SAE 6125
10. SAE 6195

THE ALLOY STEELS

ALLOYING ELEMENTS AND THEIR USE

Strength of Materials – Machinists – Unit VIII Information Sheet No. 4

OBJECTIVE:

To learn how the alloying steels are used in the construction of machines and tools.

RELATED INFORMATION:

All steels contain a certain percentage of carbon. In the SAE specifications, the carbon steel listed in the 1xxx division, means the product has a certain percentage of carbon to give it hardness. With the development of higher grades of steel for cutting tools, the carbon steels find use in bar, rod, and wire products and forgings.

Some uses of alloy steels follows:

Manganese steel is very tough, hard, and a difficult material to drill. It finds use as jaw crushers, burglar-proof safes, and other places where design calls for this type of steel.

Nickel added to iron and carbon makes a steel that is tough, strong, fatigue-resisting, and rust-resisting. In the 23xx class, the steel can be rolled and forged easily and is used to make automobile parts, boiler plate, armor plate, and saws. The 25xx type of nickel steel takes the place of platinum wire in light bulbs because the coefficient of expansion is the same as glass.

Chromium steel is a very hard and tough material finding considerable use in bullets, armor plate, files, ball bearings, and cutting tools.

As an alloy, *vanadium* increases the strength of steel and refines the grain of the steel. Automobile parts, high-speed tools, springs, heavy-duty shafts, forgings, and castings are uses of vandium steel.

Low-percentage *silicon steels* find use in springs, while those with a higher percentage are used for electromagnets. Silicon added to steel castings increases their tensile strength.

A high-grade steel is formed with the addition of *tungsten.* Lathe tools, cutters, drills, and reamers make full use of the tungsten steel.

ALLOYING ELEMENTS AND THEIR USE

SHOP ____________________ NAME ____________________________________

CLASS ____________________ INFORMATION SHEET NO. 8-4

PROBLEM

Match the use of the steels with their SAE number.

_____ a. 1070
_____ b. 2340
_____ c. 9260
_____ d. 52100
_____ e. 4140
_____ f. 51335
_____ g. 6150
_____ h. 4340

1. Aircraft forgings
2. Diesel engine crankshaft
3. Kitchen knives
4. Heavy-duty shafts
5. Cold-rolled bar stock
6. Automobile spline shaft
7. Leaf springs
8. Balls for ball bearings

THE ALLOY STEELS

ALLOYING EFFECTS

Strength of Materials – Machinists – Unit VIII Job Sheet No. 1

OBJECTIVE:

To learn the effects of alloying elements with steel.

WANTED:

Reasons for alloying steels.

RELATED INFORMATION:

There are many combinations of properties that can be made by alloying metals. If you know the properties of the alloy, then it is possible for you to use the alloy in its proper place. Greater strength, more wear resistance, and other qualities have made alloys as important as they are with respect to pure metals in the industrial world.

Since the beginning of the 20th century, men have tried to understand and control the metals and their alloys. Look into the newspaper and you will see the vast amounts being spent for metal research. The work in chemical research, fine structural analysis, and heat and cooling changes of metals and alloys is a daily occurrence. The resulting knowledge is useful in the production of many objects that form a daily pattern in our lives. For example, stainless steel can be found replacing plated trim on automobiles or replacing the silverware in your home.

TOOLS AND MATERIALS:

Furnace, Jominy End Quench fixture, grinder, Rockwell Hardness Tester, one piece C-1095 carbon steel, one piece deep-hardening tool steel.

PROCEDURE: (To be done in the machine shop)

1. Identify by marks each sample and measure hardness of each.
2. Heat samples to recommended quenching temperatures.
3. Remove each bar in turn from furnace and place in Jominy End Quench fixture.
4. After complete quenching, grind bar flat on one side. Measure Rockwell hardness each $\frac{1}{8}$ inch. (Avoid heat by using proper coolant).
5. Record results of Rockwell tests.

ALLOYING EFFECTS

SHOP ____________________ NAME ________________________________

CLASS ____________________ JOB SHEET NO. 8-1

QUESTIONS

1. Which bar had the deepest hardness?
2. How long should the Jominy test bar remain in the cooling fixture?
3. What are two possible effects of alloying?
    a.
    b.
4. Is tool steel more or less expensive than other grades of steel? Why?
5. Give the maximum safe operating temperature of a high-speed tool bit.
6. Did any of the pieces crack due to the hardening operation?
7. Is corrosion resistance an important part of steel alloys? Why?
8. What is a protective coating for iron?
9. Which element has the greatest effect on improving steel's hardening ability?
10. What does red hardness mean?

Ask your instructor for Achievement Test No. 8 after you have completed this unit's work.

THE PRODUCTION OF CASTINGS

CLASSIFICATION OF CASTING PROCEDURES

Strength of Materials – Machinists – Unit IX Information Sheet No. 1

OBJECTIVE:

To learn how casting procedures are classified.

RELATED INFORMATION:

For various uses, metals and alloys must be made into articles having a definite size and shape. These articles can be made most economically from molten metal by casting processes.

The term casting is used when one speaks of making a solid mass of metal or alloy whose shape will not be altered or changed.

Castings are made by pouring molten metal into sand molds, into permanent metal molds, by die casting, and centrifugal casting.

Most iron and steel castings are made in sand molds because of the difficulty in finding a metal mold material that can stand up under the high temperatures. The practice of using metal molds is common to the non-ferrous metal casting industries. Die casting is limited to mass production due to the initial cost. Centrifugal casting has found application in the production of large size tubing or pipe of cast iron, steel, bronze, gun metal, nickel, monel, aluminum, and lead. This process is limited to making simple shapes that are round or nearly round.

CLASSIFICATION OF CASTING PROCEDURES

SHOP ____________________ NAME ____________________________________

CLASS ____________________ INFORMATION SHEET NO. 9-1

QUESTIONS

1. What is meant by casting?

2. Why are most iron and steel castings made in sand molds?

3. Name the various types of castings.

4. Why is the use of die casting limited?

5. Where is centrifugal casting used?

THE PRODUCTION OF CASTINGS

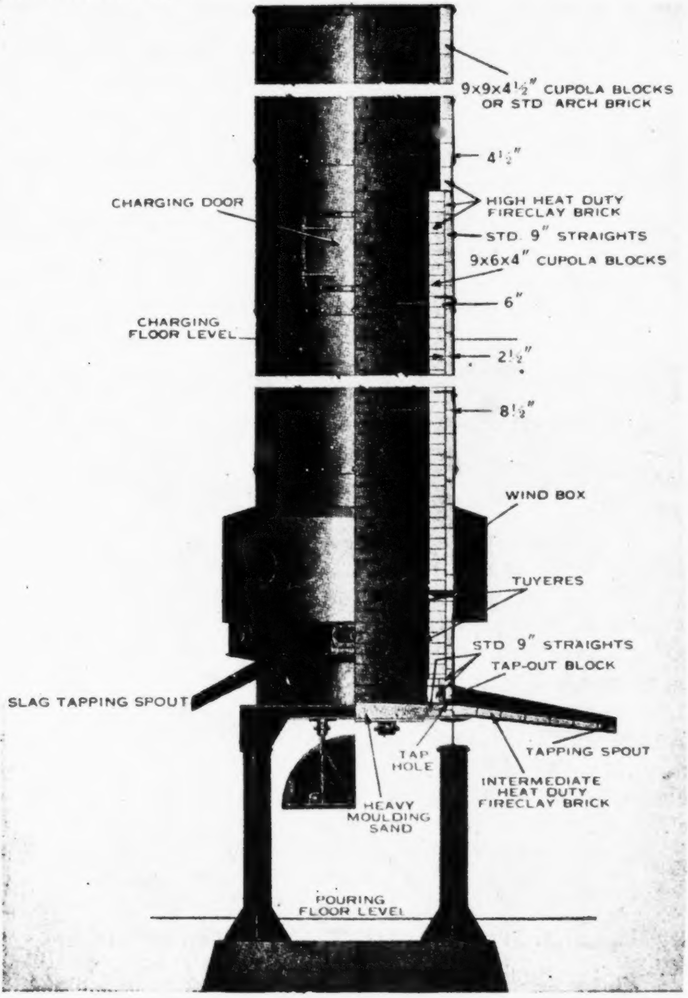
MELTING METALS FOR CASTING

OBJECTIVE:

To learn how the metal for making casting is melted.

RELATED INFORMATION:

Metal for gray iron castings is made by melting pig iron and scrap iron in a cupola furnace (see Fig. 1). The furnace is a vertical, round, steel structure lined with fire-clay brick. A door near the top is used to charge the furnace. The charge is made up of layers of coke, limestone, and pig iron and scrap. Normal air is supplied through tuyeres near the bottom of the furnace. Below the tuyere level, tap holes and spouts are used to withdraw slag and molten iron.


9x9x4½" CUPOLA BLOCKS OR STD ARCH BRICK
4½"
CHARGING DOOR
HIGH HEAT DUTY FIRECLAY BRICK
STD. 9" STRAIGHTS
9x6x4" CUPOLA BLOCKS
6"
CHARGING FLOOR LEVEL
2½"
8½"
WIND BOX
TUYERES
STD 9" STRAIGHTS
TAP-OUT BLOCK
SLAG TAPPING SPOUT
TAP HOLE
TAPPING SPOUT
INTERMEDIATE HEAT DUTY FIRECLAY BRICK
HEAVY MOULDING SAND
POURING FLOOR LEVEL

The cupola furnace

FIG. 1

The cupola, while efficient as an iron-melting type of furnace, does not permit the control or changing of the metal mixture. The air furnace (reverberatory type) fired by coal, powdered coal, or oil allows modifying of the batch being melted and finds use in making metal for malleable and alloy iron castings.

The electric-furnace melting is used when high-grade malleable and alloy iron castings are required.

Melting for steel castings is done in small Bessemer converters, open-hearth furnaces, or electric furnaces.

In the non-ferrous foundry practice, melting furnaces are divided into two classes:

1. Metal for casting comes in contact with the products of combustion (air reverberatory furnaces and small oil or gas fired open-hearth furnaces).

2. Metal for casting is protected from products of combustion (crucible and electric furnaces).

Non-ferrous alloys are melted for casting without any attempt to change their mixture except by alloying additions. Owing to the higher cost of making non-ferrous alloyed castings, much care is taken in melting the alloys to keep the melting quality high and melting losses low.

MELTING METALS FOR CASTING

SHOP ____________________ NAME ____________________________________

CLASS ____________________ INFORMATION SHEET NO. 9-2

QUESTIONS

1. Name the furnaces in which each of the following gets the metal for its castings:

   a. gray iron castings
   b. non-ferrous alloyed castings
   c. high-grade malleable castings
   d. steel castings

2. Why is the air furnace used instead of the cupola furnace?

3. Why is much care taken in the non-ferrous foundry practice?

4. What charge is used in the cupola furnace?

5. Name the two classes of non-ferrous melting furnaces.

   a.

   b.

THE PRODUCTION OF CASTINGS

PATTERNS

Strength of Materials – Machinists – Unit IX Information Sheet No. 3

OBJECTIVE:

To learn how patterns for casting are made.

RELATED INFORMATION:

The first step in the production of a sand casting is to make a pattern. A pattern is a wood or metal copy of the required article enlarged slightly to allow for shrinkage that occurs when metals cool. The allowance for shrinking of metals follows:

1. Gray cast iron – $\frac{1}{8}$" per ft.
2. White cast iron and steel – $\frac{1}{4}$" per ft.
3. Copper and brass – $\frac{3}{16}$" per ft.
4. Lead and zinc – $\frac{5}{16}$" per ft.

When a quantity of small parts is to be made, they can be gated. The patterns are connected by channels or runners that permits the flow of the molten metal to each of the castings. After cooling, the gates are cut off and the surface of the casting ground smooth.

The woods generally used for patterns are white pine, mahogany, cherry, maple, and birch. White pine is considered the best of the woods mentioned because it can be worked easily, takes glue and varnish and stands up fairly well under use.

Pattern wood should be well seasoned to prevent warping or shrinking.

Patterns that are to be used more than once are varnished to protect against moisture.

Metal patterns of brass, cast iron, aluminum or steel are made from an original wood pattern and are used where constant use makes wood patterns impractical. Some companies have had success with plastic patterns instead of metal ones. The process is a little more complicated than the making of a metal pattern, but manufacturing costs have been cheaper with plastic.

PATTERNS

SHOP ____________________ NAME ________________________________

CLASS ____________________ INFORMATION SHEET NO. 9-2

QUESTIONS

1. What is a pattern?

2. Give the shrinkage allowance on patterns for the following materials:
    a. Steel
    b. Brass

3. Why is white pine considered the best wood in the making of patterns?

4. What materials are metal patterns made of?

5. Why should well-seasoned lumber be used in making patterns?

THE PRODUCTION OF CASTINGS

SAND CASTING

Strength of Materials – Machinists – Unit IX Job Sheet No. 1

OBJECTIVE:

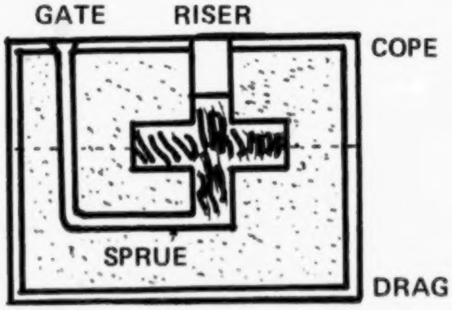
To learn how a sand casting is made in a mold.

WANTED:

Steps in making a sand casting.

RELATED INFORMATION:

Sand casting is used to eliminate the high cost of machining an object to specified sizes. It is usually done when a job is too complicated to machine or the number of parts is so great that it is cheaper to cast. The machinist's work consists of finishing the object.



CROSS-SECTION SAND CAST MOLD

TOOLS AND MATERIALS:

Molding flask, green sand, parting sand, moldboard, wood pattern, lead, ramming tools.

PROCEDURE:

1. Place drag part of pattern, bottom side up, on moldboard.
2. Surround with drag of flask.
3. Ram green sand between pattern and flask.
4. Place bottom board over drag and invert.
5. Put cope of pattern on top of drag pattern and surround with cope of flask. Connect cope and drag of flask.
6. Sprinkle parting sand around over drag area.

7. Ram green sand between flask and pattern.

8. Provide for gate and riser and any other vent holes.

9. Break flask into its two parts and remove pattern. Remove loose sand.

10. Close flask and start pouring lead into gate. (Lead is used because of low melting point).

11. Allow to cool.

12. Break open flask to see result of pattern.

13. Students record results of experiment, noting procedures, casting defects, etc.

14. Students should ask any questions on procedures that were not clear.

SAND CASTING

SHOP ____________________ NAME ____________________________________

CLASS ____________________ JOB SHEET NO. 9-1

QUESTIONS

1. Why are sand castings used?

2. Which part of the flask is the drag?

3. Which part of the flask is the cope?

4. Why is the pattern split?

5. Explain the use of parting sand.

6. Why is green sand used?

7. Give the reasons for using a gate and riser.

8. What wood was used in the pattern? Why?

THE PRODUCTION OF CASTINGS

METAL MOLDING

Strength of Materials – Machinists – Unit IX Information Sheet No. 4

OBJECTIVE:

To learn how castings are made in a metal mold.

RELATED INFORMATION:

When a large number of the same metal part is to be made by casting, it is better to carry out the operation in permanent metal molds. These molds can be used over and over again, thus doing away with the work of rebuilding or repairing the sand molds for each casting.

Owing to the high temperatures that occur for iron and steel castings, it is difficult to find a permanent mold material.

On the other hand, non-ferrous alloys are cast in metal molds, making sounder, cleaner castings with very good mechanical properties.

Permanent metal molds consist of two cast-iron halves with the parting surface arranged in a vertical direction. Openings in metal mold castings are made by using steel or sand cores. In some cases slightly tapered steel cores pass through the mold wall. They can be removed independently of the operation of the mold.

The molten metal flows into the permanent mold under the force of gravity. The mold is vented to permit the escape of gases and has risers to feed metal to the casting.

Owing to their higher thermal conductivity (rate at which heat passes through a metal) castings become solid and cool much more quickly in metal molds than in sand molds.

METAL MOLDING

SHOP ____________________ NAME ____________________________________

CLASS ____________________ INFORMATION SHEET NO. 9-4

QUESTIONS

1. When are metal molds used? Why?

2. Why is it difficult to find permanent mold materials for iron and steel castings?

3. Give some reasons for using metal molds in the casting of non-ferrous alloys.

4. Is making castings in a metal mold the same as in a sand casting? Explain.

5. What do you mean by high thermal conductivity?

THE PRODUCTION OF CASTINGS

DIECASTING

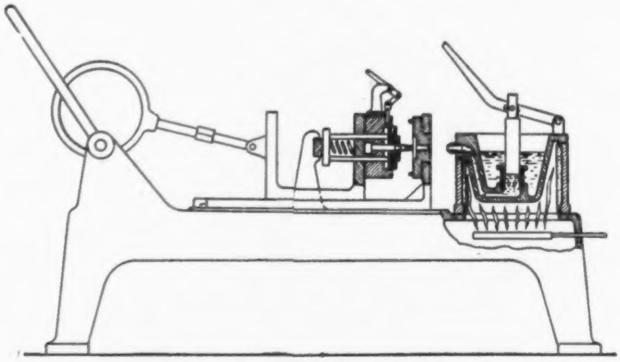
Strength of Materials – Machinists – Unit X Information Sheet No. 5

OBJECTIVE:

To learn how castings are made by die casting.

RELATED INFORMATION:

In the die-casting process, molten metal is forced under pressure through a gate into a die (see Fig. 1).



Plunger-type die-casting machine

FIG. 1

Dies made of plain carbon steel can be used for tin and lead alloy castings, while chromium-vanadium or chromium-tungsten-cobalt steels are used for dies when casting aluminum and zinc alloys.

The pressure for forcing metal into the die is done by the forward motion of a piston in a cylinder with molten metal. The cylinder in which the plunger operates is sunk under hot metal in a pot. The metal fills the cylinder through a side port on the upstroke of the plunger.

Dies should be water cooled and provided with vents on the parting surface to allow the air to escape. The casting will stick to the side of the die with the larger portion of the cast part. This side has some means for pushing the casting out of the die.

With die casting a smooth, clean cast part which requires little finish work can be made.

Die casting is used in mass production processes where initial cost of making the dies can be economically paid off. The high speed of the process and the low cost of needed finishing are sound arguments for using die casting methods.

DIE CASTING

SHOP ____________________ NAME ______________________________

CLASS ____________________ INFORMATION SHEET NO. 9-5

QUESTIONS

1. What type of steel is used in the dies for making tin and lead alloy castings?

2. What type of steel is used in the dies for making aluminum and zinc alloy castings?

3. Give the advantages of die casting.
   a.
   b.

4. State the disadvantage of die casting.

THE PRODUCTION OF CASTINGS

CENTRIFUGAL CASTING

Strength of Materials – Machinists – Unit IX Information Sheet No. 6

OBJECTIVE:

To learn how simple round or nearly round shapes are made by centrifugal casting.

RELATED INFORMATION:

The centrifugal casting machine consists of a refractory or metal round mold which turns at speeds up to 10,000 rpm (revolutions per minute).

Pouring spouts are provided at one or both ends of the mold. The metal fed to the mold is watched very carefully in order to maintain an even flow of material. The pressure on the metal due to the force of the circular motion gives a more dense, finer-grain structure, and better mechanical properties than in sand casting.

The metal nearest the center of the rotating axis of the round mold gives the same results as the metal in the gates and risers of the sand castings. This layer, which is porous and has a large amount of impurities, can be machined from the inner surface of the casting.

The principal users of centrifugal castings have been the large-size pipe and tubing industries. The castings are made in many different types of metals.

CENTRIFUGAL CASTING

SHOP ____________________ NAME ________________________________

CLASS ____________________ INFORMATION SHEET NO. 9-6

QUESTIONS

1. Where is centrifugal casting used?

2. Give some reason for making this type of casting.

3. What does the centrifugal casting machine consist of?

THE PRODUCTION OF CASTINGS

DEFECTS IN CASTINGS

Strength of Materials – Machinists – Unit IX Job Sheet No. 2

OBJECTIVE:

To learn what defects to look for in castings.

WANTED:

Results of examination of castings.

RELATED INFORMATION:

It is safe to say that a perfect casting has yet to be made, but ones that are being produced are reasonably free from defects. The principal defects are:

1. Rounded-off edges
2. Cooling cracks
3. Shrinkage cracks
4. Blowholes
5. Pinholes
6. Shrinkage cavities

Cooling cracks are found in brittle alloyed castings such as cast iron. They are caused when stresses develop due to different rates of cooling in the casting.

Shrinkage cracks develop during high temperatures mostly in non-ferrous alloys. Certain regions of the casting remain in the liquid state and can be ruptured or split with very little force.

Shrinkage cavities occur when proper design is not followed. These cavities should form outside of the casting in the gates.

Blowholes (larger than pinholes) result from trapped air due to improper venting and feeding, or from gases resulting in casting.

Pinholes come from trapped gas coming out of solution during the time the casting is becoming solid.

There are several methods used in industry to discover defects in castings. They are the X-Ray inspections for not too thick sections, the radio-graphic method for heavier sections, and the magnaflux method.

The magnaflux method reveals surface or near-surface cracks in steel. The surface of a casting is covered with suspended fine iron or magnetite powder, after or while being magnetized. Cracks are shown by local clusters of the powder.

TOOLS AND MATERIALS:

Hacksaw; iron, steel and brass castings.

PROCEDURE: (To be done in the machine shop)

1. Examine the surface of the castings for defects.
2. Cut castings in half with hacksaw.
3. Examine castings for defects.
4. Note your results.

DEFECTS IN CASTINGS

SHOP ______________________ NAME ______________________________________

CLASS ____________________ JOB SHEET NO. 9-2

QUESTIONS

1. What are the principal defects found in castings:
    a.
    b.
    c.
    d.
    e.
    f.

2. How does industry discover these defects?
    a.
    b.
    c.

3. Explain the defects found on the surface of sample castings.

4. What defects did you find on the inside of the castings? Explain.

Ask your instructor for Achievement Test No. 9 after you have completed this unit's work.

NON-FERROUS ALLOYS

COPPER

Strength of Materials – Machinists – Unit X   Information Sheet No. 1

OBJECTIVE:

To learn the non-ferrous alloys of copper and how they are used.

RELATED INFORMATION:

Steel is not the only alloying metal. There are a number of combinations of elements in the non-ferrous metals which make them important non-ferrous alloys.

Copper is alloyed with several different metals because the resulting mixture is stronger and harder than pure copper, easier to cast and machine, has greater corrosion resistance, higher elastic nature, and is cheaper.

While annealing is the only method used to heat-treat pure copper, other types of treatments besides annealing are used with some of the copper alloys. For example, the alpha brasses (gilding metal, low brass, yellow brass, etc.) are annealed after cold-working, while on aluminum-bronze, a solution and precipitation type treatment is used.

Copper alloys can be divided into two main classes: the brasses (alloys of copper and zinc) and the bronzes (alloys of copper and tin). A note of caution should be followed when specifying these materials because terms of the brass industry are misleading.

For example, the term commercial bronze may be used when referring to some compositions of copper-zinc.

With a range of 5 to 45 percent of zinc, the brasses are among the most useful alloys. A chart of their composition, use, and properties follows.

COMPOSITION, USES, AND PROPERTIES OF BRASSES

NAME	Composition %		COLOR	TYPICAL USES	TEMPER	Tensile strength psi	Elongation in 2 in., %
	Cu	Zn					
Muntz metal	59	41	Reddish	Architectural work, welding rod, condenser, tubes, valve stems	Hot-rolled	54,000	45
					Cold-rolled	80,000	5
Extruded rivet metal	63	37		Rivets, screws	Rivet	60,000	30
High brass	66	34	Typical brass color	Stamping, Blanking, drawing, spinning, forming, radiator cores, springs, screws, rivets, grill work, chains	Light anneal	53,000	54
					Soft anneal	46,000	64
					Hard	76,000	7
					Rivet	60,000	30
					Spring	125,000	
Cartridge or spinning brass	70	30		Cartridges, eyelets, tubes, spinning, drawing	Light anneal	53,000	54
					Soft anneal	46,000	64
					Hard	76,000	7
					Spring	92,000	3
Brazing brass	75	25		Drawing, spinning, springs; particularly suited for brazing	Light anneal	52,000	50
					Soft anneal	45,000	62
					Hard	76,000	7
					Spring	125,000	
Low brass	80	20	Red gold	Drawing, forming, flexible hose	Light anneal	47,000	47
					Soft anneal	43,000	55
					Hard	75,000	7
					Spring	120,000	

COMPOSITION, USES, AND PROPERTIES OF BRASSES

NAME	Composition %		COLOR	TYPICAL USES	TEMPER	Tensile strength psi	Elongation in 2 in., %
	Cu	Zn					
Rich low brass	83	17	)	Fourdrinier wire	Soft	42,000	
Red brass	85	15	Red	Hardware, radiator cores, plumbing pipe, condenser tubes, flexible hose	Light anneal	45,000	48
					Soft anneal	40,000	43
					Hard	71,000	5
					Spring	83,000	3
Commercial	90	10	Bronze	Screen wire, hardware, trim, forgings, screws, rivets, costume Jewelry	Light anneal	41,000	42
					Soft anneal	38,000	56
					Hard	64,000	4
					Spring	73,000	3
Gilding metal	95	5	Copper	Drawing, spinning, forming	Light anneal	35,000	42
					Soft anneal	36,000	44
					Hard	55,000	4
					spring	65,000	3

Looking over this list, you can see the many varieties of uses that the copper alloys find in our daily necessities. The copper plumbing for easier and safer water supply and the screen wire for healthier living are some examples of the improvements brought by alloys.

The mechanical properties or corrosion resistance of the brasses can be greatly improved by the adding of a small amount of one or more other metals.

Some of the more common metals that can be added are noted below:

NAME	% Composition			TYPICAL USE
	Cu	Zn	Others	
Aluminum Brass	76	22	2.0 Aluminum	Corrosion-resisting materials
Naval Brass	60	39	1.0 Tin	Marine Shafting, bolts, forgings
Tobin Bronze	59	38	2.0 Tin 1.0 Iron	Corrosion-resisting material
Manganese Brass	60	38	0.75 Tin 0.75 Iron 0.5 Manganese	Pump rods, valves and cylinders, tubes, nuts, bolts, propellers
Iron Brass	56	41	2.0 Iron 0.5 Manganese 0.5 Tin	Casting material
Lead Brass	65	32	3.0 Lead	Lighting fixtures, keys
Silicon Brass	78	20	2.0 Silicon	Fire extinguisher shells

Tin increases the strength, hardness and durability of copper to a much greater extent than zinc. The most useful bronzes are those containing 8 to 11 percent of tin.

The composition and use of the bronzes follow:

NAME	% Composition			TYPICAL USE
	Cu	Tin	Others	
Bell metal	80	20		Bells and gongs
Speculum metal	66	34		Mirrors and reflectors
Phosphor bronze	92	8	.05 Phosphorus	Springs, bearings, welding rod
Bearing bronze	75	10	15.0 Lead	Heavy load bearings
Aluminum bronze	88	0.5	8.0 Aluminum 3.0 Iron	Condenser tubes and gift articles
Silicon bronze	96	0.5	3.5 Silicon	Tanks, bolts and chain
Beryllium bronze	98		2.0 Beryllium	Springs and cutting tools

There are several copper-nickel alloys that are known as manganin, a resistance wire with very low temperature coefficient of resistance, composed of 80% copper, 5% nickel, and 15% manganese, and nickel or German silvers containing 65% copper, 20% zinc, and 15% nickel,which are used as the base metal for plated silverware and the metal for high-grade plumbing and hardware.

COPPER

SHOP ____________________ NAME ________________________________

CLASS ____________________ INFORMATION SHEET NO. 10-1

QUESTIONS

1. Why is copper alloyed with other metals?

2. Name the three classes of copper alloys.
    a.
    b.
    c.

3. How can the mechanical properties or corrosion-resistance of the brasses be improved?

4. Why is tin alloyed with copper?

5. Give typical uses of the following:
    a. Naval brass
    b. Silicon bronze
    c. Speculum metal
    d. Muntz metal
    e. Gilding metal
    f. Beryllium copper
    g. Manganin

NON-FERROUS ALLOYS

ALUMINUM

Strength of Materials – Machinists – Unit X Information Sheet No. 2

OBJECTIVE:

To learn the non-ferrous alloys of aluminum and how they are used.

RELATED INFORMATION:

Over 50% of the aluminum produced is used in the alloy form. The aircraft industries gave an increased rise to the development because of the light weight, although recent trends show the automobile, railroad and building fields making more and more use of the material.

The aluminum alloys can be divided into two classes: casting (cast in either sand or permanent molds) and wrought (mechanically shaped or formed) alloys.

Some of the cast and wrought alloys along with their composition and use are listed below:

CAST ALLOYS

DESIGNATION	% COMPOSITION	USE
SAE 33	90 Aluminum 8 Copper 1 Silicon 1 Iron	General casting alloy
SAE 38	96 Aluminum 4 Copper	High strength, heat-treated casting
SAE 322-1	93.5 Aluminum 1 Copper 5 Silicon 0.5 Manganese	Liquid-cooled cylinder heads
Alcoa 195 T 6	96 Aluminum 4 Copper	Aircraft, marine, bus and engine parts

WROUGHT ALLOYS

DESIGNATION	% COMPOSITION *	USE
SAE 25	99 Aluminum	Cooking utensils
SAE 29	97 Aluminum 1.5 Manganese .2 Copper	Sheet metal work
SAE 26 (Duralumin)	92 Aluminum 1 Manganese 4.5 Copper .5 Magnesium	Strong alloy. Structural shapes, bolts and nuts, screws, rivets, forgings
SAE 24	92 Aluminum 4.5 Copper 1.5 Magnesium .5 Manganese	Aircraft construction

The softer grades of aluminum alloys are more difficult to machine than the harder alloys. Greater rake and clearance angle on cutting tools,and kerosene or mixtures of kerosene and lard oil are used when machining aluminum alloys.

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* Approximate

ALUMINUM

SHOP ____________________ NAME ____________________________________

CLASS ____________________ INFORMATION SHEET NO. 10-2

QUESTIONS

1. Why is aluminum used in the aircraft industry?

2. Name the types of aluminum alloys.

3. Give the use of the following alloys:
    a. SAE 24
    b. SAE 29
    c. SAE 33
    d. SAE 322-1

4. Describe cutting-tool use and lubricant called for in the machining of aluminum alloy.

NON-FERROUS ALLOYS

MAGNESIUM

Strength of Materials – Machinists – Unit X Information Sheet No. 3

OBJECTIVE:

To learn the non-ferrous alloys of magnesium and how they are used.

RELATED INFORMATION:

Magnesium alloys are second in importance to the aluminum alloys as light structural material. The most outstanding of the light magnesium alloys is the range sold under the trade name Dow Metal.

The outstanding characteristics of Dow Metal are:

1. Extreme lightness ($\frac{2}{3}$ as heavy as aluminum alloys).
2. Tensile strength from 18,000 to 35,000 psi.
3. Forged and extruded parts do not require heat treatment.
4. Easily machined.
5. Good corrosion resistance except when exposed to salt water and iron.

Some of the types, compositions, and uses of magnesium alloys are:

TYPE	% COMPOSITION	USE
SAE 500	90.8 Magnesium 6.0 Aluminum .2 Manganese 3.0 Zinc	Sand castings
SAE 501	90.2 Magnesium 9.0 Aluminum 0.2 Manganese 0.6 Zinc	Die castings

TYPE	% COMPOSITION	USE
SAE 520 or 521	93 to 94 Magnesium 3 to 6 Aluminum 0.2 Manganese 1 to 3 Zinc	Structural shapes, tubing, rods, bars
SAE 51	98.5 Magnesium 1.5 Manganese	Rolled plate, sheet or strips
DOW J, L, M, O or X	91 to 94 Magnesium 3 to 9 Aluminum .2 Manganese 1 to 3 Zinc (L has tin or cadmium instead of zinc)	Press and hammered forgings

MAGNESIUM

SHOP ____________________ NAME ________________________________

CLASS __________________ INFORMATION SHEET NO. 10-3

QUESTIONS

1. How do magnesium alloys rate?

2. Give the outstanding characteristics of Dow Metal.

3. Give use of each of the following alloys:
    a. SAE 51
    b. SAE 501

4. How can magnesium alloys be machined without lubricants?

NON-FERROUS ALLOYS

ALUMINUM AND MAGNESIUM

Strength of Materials – Machinists – Unit X Job Sheet No. 1

OBJECTIVE:

To see how aluminum and magnesium alloys can be machined.

WANTED:

Results of machining the alloys.

TOOLS AND MATERIALS:

Lathe, Bar stock of Alcoa 11sT3 and Dow Chemical Co. J.

PROCEDURE: (To be done in machine shop by instructor)

1. Set up aluminum alloy in lathe.
2. Show comparison of cutting tool with one normally used on steel.
3. Make cut on stock,explaining lubricant used and any precautions necessary.
4. Have students record the information.
5. Set up magnesium alloy in lathe.
6. Make cut and explain precautions to students.
7. Have students record the information.

NON-FERROUS ALLOYS

NICKEL

Strength of Materials – Machinists – Unit X Job Sheet No. 2

OBJECTIVE:

To learn the non-ferrous alloys of nickel and their uses.

WANTED:

Differences in the various nickel alloys.

RELATED INFORMATION:

The nickel-copper alloys have been explained, but the use of a great percentage of nickel gives us some very good alloys.

A most important alloy containing 67% nickel, 28% copper and the remainder of the mixture iron with a small amount of manganese, silicon, and carbon is Monel metal. It has great corrosion resistance and is used in dye vats, sinks, hot water boilers, and kitchen equipment.

Heat-resisting and electrical-resistance alloys are named nichrome and chromel. They contain about 62% nickel, 15% chromium, and the remainder iron with small amounts of carbon.

The low-thermal-expansion alloys are the Invar or iron-nickel alloys containing about 30 to 40% nickel. Measuring tapes, instruments, watches and struts for aluminum-alloy pistons are important uses of this alloy.

Finally, the magnetic alloys containing iron, nickel, and sometimes cobalt in varying amounts, find use as permanent magnets.

TOOLS AND MATERIALS:

Pieces of brass, bronze, Monel metal, nichrome, Invar, Alnico, steel, file, microscope, furnace, electrical leads.

PROCEDURE: (To be done in machine shop by instructor)

1. Test each of the pieces of metal to see if they will attract the piece of steel. Have students record results.

2. File each piece and collect filings. Be sure file is clean after each sampling.

3. Observe filings under microscope. Have students record their observations.

4. Show low thermal expansion of Invar. Have students record results.

5. Show the heat-resisting and electrical resistance of nichrome. Have students record results.

NON-FERROUS ALLOYS

SOLDERS AND BRAZING

Strength of Materials – Machinists – Unit X Job Sheet No. 3

OBJECTIVE:

To learn of alloys that can be used to join surfaces of metal.

WANTED:

Results of soldering materials.

RELATED INFORMATION:

Solder is an easy-melting alloy used to join the surfaces of metals, while the brazing alloy has a higher melting point than the lead-tin solder, yet melts below the melting point of the metals being joined.

The flux (gathers up or dissolves oxide or other matter on the surface of metal) for solder is zinc chloride and for brazing is a mixture of borax and boric acid.

Brazing has been to a large extent taken over by welding practices because of stronger adhesion (sticking together) of the metal by the latter method.

TOOLS AND MATERIALS:

Soldering iron, solder, acid or soldering paste, two pieces of clean sheets of copper.

PROCEDURE:

1. Heat iron.
2. Place acid or paste on parts of copper to be fastened together.
3. Lap pieces of copper, making the coated pieces face each other.
4. Solder along joints.
5. Allow to cool and test results.
6. Record your observations as to strength of joints, how solder was melted, amount of solder used, etc.

NON-FERROUS ALLOYS

BEARING METALS

Strength of Materials – Machinists – Unit X Information Sheet No. 4

OBJECTIVE:

To learn the use and composition of bearing metals.

RELATED INFORMATION:

Since there is much wear on machinery, a metal had to be made that could be soft enough to mold itself about a shaft, with good resistance to wear. The requirement has been attained by use of an alloy containing hard grains in a soft natural material. This structure is found in the white alloys (lead, tin, antimony, copper).

Most popular of the white alloys is "Babbitt metal" which is expensive because of the large amount of tin used as the hard-grain part of the alloy, but gives better service because of the make-up of the alloy.

The bronzes to which a large amount of lead has been added are used as bearing metals, too. But their composition differs, in that they are made up of soft grains in a hard natural material. The leaded bronzes are of poorer quality than the white alloys because they do not give or mold about the shaft as well.

A new type of bearing material is a porous self-lubricating type consisting of bronze alloys. Porous bearing alloys can soak up large amounts of oil. This oil is held in the pores of the bearing metal until pressure causes it to flow out onto the surfaces of the bearing. Thus, the term, self-lubricating.

Bearing metals find many uses in bearings that are used in the industrial world in various ways.

BEARING METALS

SHOP ____________________ NAME ____________________________________

CLASS ____________________ INFORMATION SHEET NO. 10-4

QUESTIONS

1. How do white alloys differ from the leaded bronzes as a bearing metal?

2. Give the composition of each of the bearing metals.

3. How does the self-lubricating bearing get its name?

4. Give some examples of where bearing metals are used in the machine shop.

Ask your instructor for Achievement Test No. 10 after you have completed this unit's work.

THE STRUCTURE OF METALS

CRYSTALS AND THEIR FORMATION

Strength of Materials – Machinists – Unit XI Information Sheet No. 1

OBJECTIVE:

To learn the crystal formation of metals.

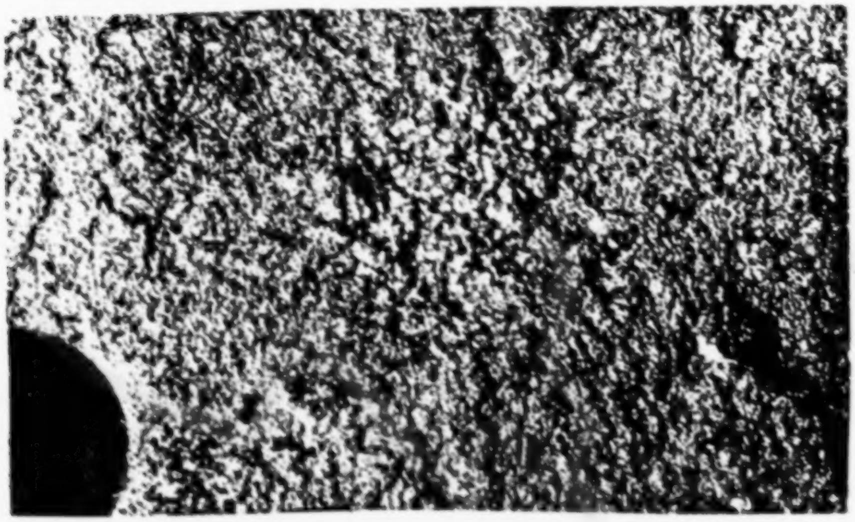
RELATED INFORMATION:

As you have learned, metals having strength together with an ability to deform without rupture are of great importance in the mechanical and structural field. In addition, the many other physical and mechanical properties have a bearing on the structure of metals.

The structure of metals depends on two characteristics:

1. How the atoms are composed.
2. How the atoms are arranged.

When a metal changes from a liquid to a solid state, it crystallizes. (See Fig. 1)



ENLARGED VIEW OF CRYSTAL STRUCTURE

FIG. 1

During the process of becoming solid, the atoms of the liquid metal arrange themselves, forming a definite space pattern. The pattern formed is known as the space lattice (see Fig. 2)

You will notice it is a series of points in space formed in a variety of geometrical patterns. The one shown in Fig. 2 is a simple arrangement.

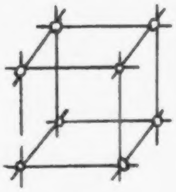


FIG. 2

Although the atoms are too small to be seen by the eye, the space-lattice diagram has been determined by X-Ray crystal-analysis methods. This method has shown the cubic pattern (Fig. 2) to be the crystal structure of copper, iron, aluminum, lead, nickel, etc. Some of the metals assume the body-centered cubic pattern, see Fig. 3. There are many formations of the metals which can be found in books on metallurgy.

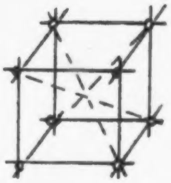


FIG. 3

To help you see the change from a molten state to a crystal formation, it will be shown to you step by step. A crystal seed forms as shown in Fig. 4.

FIG. 4

The seed proceeds to send out shoots (see Fig. 5) forming a skeleton of a crystal in much the same way frost forms a pattern. Atoms attach themselves to the axis of the growing crystal one layer on top of another.

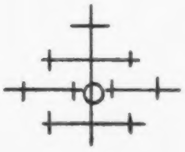


FIG. 5

Finally, the completed solid or crystal is formed as shown in Fig. 6. The nature of the crystal border is still unknown, but it is assumed it is an interlocking border line.

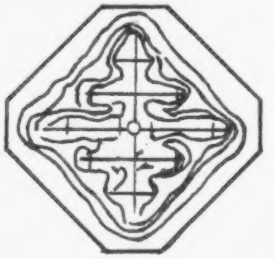


FIG. 6

The external shape of the crystal is controlled by the conditions leading to its formation. The crystals found in all commercial metals and alloys are called grains because of their variety of external shapes. A grain would be a crystal having any variety of external shape, but having an internal atomic structure based upon the space lattice with which it is born.

CRYSTALS AND THEIR FORMATION

SHOP ____________________ NAME ________________________________

CLASS ____________________ INFORMATION SHEET NO. 11-1

QUESTIONS

1. Name two characteristics upon which the structure of metal depends.
   a.
   b.

2. Define grain.

3. Make a sketch of a simple cubical space lattice structure.

4. How can a space lattice diagram be determined?

5. Sketch the three steps in the growth of a crystal.

THE STRUCTURE OF METALS

GRAIN STRUCTURE

Strength of Materials – Machinists – Unit XI Job Sheet No. 1

OBJECTIVE:

To investigate the grain structure of various metals.

WANTED:

Observations as to the difference in grain structures of metals.

TOOLS AND MATERIALS:

Microscope, heat-treating furnace, quenching bath, cast iron, mild steel, wrought iron.

PROCEDURE: (To be demonstrated by the machine shop instructor)

1. Fracture metals and examine structure under microscope.
2. Heat each of the metals to above the critical range and fast-cool. Fracture and observe grain structure under microscope.
3. Instructor will explain change that has taken place.

THE STRUCTURE OF METALS

DEFORMATION OF METALS

Strength of Materials – Machinists – Unit XI Job Sheet No. 2

OBJECTIVE:

To learn what takes place when metals are deformed.

WANTED:

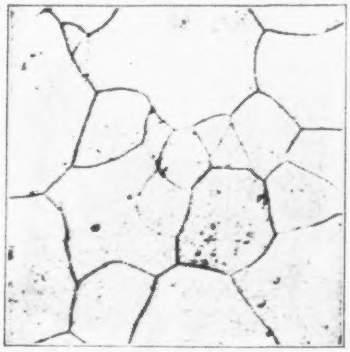
Results of deformation.

RELATED INFORMATION:

Knowing that metals are composed of many crystals or grains, you must be able to see what happens when a piece of metal is bent, drawn or forged. When a force exceeding the elastic limit is applied to the metal, the crystals of the metal start to get longer by an action of slipping, which takes place within and between adjacent crystals. To understand this reaction a little more, get a deck of cards. Having set them up in an even pile, give one end a shove. The sliding between the individual cards occurs in somewhat the same way as the crystals in metals.

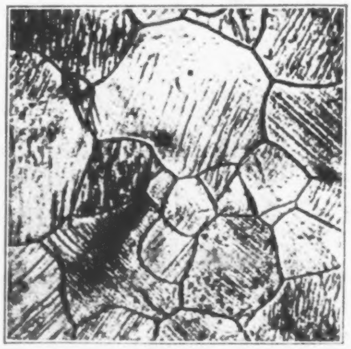
Deformation is illustrated in Figs. 1 and 2.

FIG. 1



Commercially Pure Iron before Deformation

FIG. 2



Commercially Pure Iron after Slight Plastic Deformation

Notice the dark lines within the grains in the deformed iron. You can notice a very deformed piece of metal because of these long crystals.

A permanently deformed metal undergoes the following changes in its physical properties:

1. Increased tensile strength and hardness.
2. Stiffness and machining remains about the same.
3. Ability to shape is reduced.

Continued deforming of the metal causes it to become brittle.

TOOLS AND MATERIALS:

Piece of $\frac{1}{8}$ x 4" x 4" steel with two $\frac{1}{2}$" diameter holes, vise, furnace, two pieces of wrought iron, hammer, anvil, tongs.

PROCEDURE: (To be done in the machine shop)

1. Place $\frac{1}{8}$" steel in vise with center of holes along top of vise jaws.

2. Bend metal 90°, being careful not to strike holes.

3. Remove piece of steel from vise and note how holes look on inside and outside of bend. Record results.

4. Heat pieces of iron in furnace.

5. Withdraw pieces of bright red iron from furnace, lap ends on anvil and quickly beat together. Did deformation take place? Record results.

Ask your instructor for Achievement Sheet No. 11 after you have completed this unit's work.

SIMPLE STRESS

UNIT STRESS
UNIT STRAIN

Strength of Materials – Machinists – Unit XII   Information Sheet No. 1

OBJECTIVE:

To learn what is meant by unit stress and how it is used.

RELATED INFORMATION:

Imagine that a square steel rod of 2 inches x 2 inches (Fig. 1) is put into the jaws of a testing machine. The force needed to break the bar was recorded as 200,000 lbs.

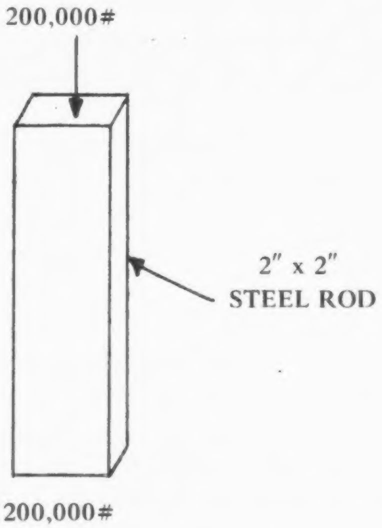


FIG. 1

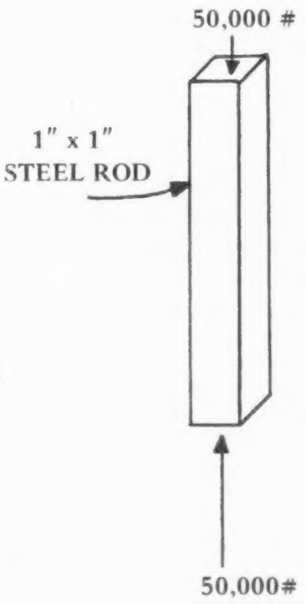


FIG. 2

Fig. 2 is a bar of the same kind of steel, but, as you notice, only measures 1 inch x 1 inch. The force needed to break this bar is 50,000 lbs., or one-fourth. This result is obtained because the area that resists the pull is only one-fourth of that of the 2 inch x 2 inch bar.

The length of the bar has no effect on the breaking load. The *cross-sectional area* and *type of material* are the factors to take into consideration when you are looking for the resisting force of the material. Mathematically, the set-up appears thusly:

$$\text{Resistance (R)} = \frac{\text{Total Force (F)}}{\text{Cross-Section Area (A)}}$$

The resistance of one square inch of the resisting area is called the *unit stress* and is measured in terms of pounds per square inch (psi).

For example, the unit stress for the 2 inch x 2 inch steel rod in Fig. 1 would be solved thusly:

$$R = \frac{F}{A} = \frac{200{,}000}{2 \times 2} = 50{,}000 \text{ psi. } \left(\frac{\#}{\text{in.}^2}\right)$$

The unit strain on the other hand is the deformation per unit of length due to a certain load. When a steel rod gets longer without breaking, each inch of the length will stretch or deform an equal amount to make up the total.

To find unit strain, divide the total strain in inches by the length of the body in inches, or:

$$\text{Unit strain (D)} = \frac{\text{Total strain (S)}}{\text{Length of body (L)}}$$

Unit strain is measured in terms of inch per inch.

An example of unit strain would be suspending a weighted object from a wire, causing it to stretch or get longer. If the amount of stretch was 0.005 inches and the original length was 50 inches, the strain would be solved thusly:

$$D = \frac{S}{L} = \frac{.005}{50} = .001 \text{ in./in.}$$

UNIT STRESS
UNIT STRAIN

SHOP ____________________ NAME ________________________________

CLASS ____________________ INFORMATION SHEET NO. 12-1

PROBLEMS

1. Find the unit stress for a 1-square-inch rod having a load of 50,000 lbs.

2. Find the unit strain for a piece of wire that is 25 inches long and stretched 0.0025 inches when a load was applied.

3. Solve the unit stress for a 1 inch x 2 inch steel bar supporting a load of 60,000 lbs.

4. What is the unit strain for a piece of material that stretched 0.005 inches when a load was applied to a wire that was 75 inches long?

5. A 2-inch-diameter steel cable $7\frac{7}{8}$ inches long has a 40,000 lbs. weight attached to it. The steel cable was measured again and found to be 8 inches long. Find the unit stress and unit strain.

SIMPLE STRESS

TENSION

Strength of Materials – Machinists – Unit XII Job Sheet No. 1

OBJECTIVE:

To learn when an object is in tension.

WANTED:

Conclusion as to when an object is in tension.

RELATED INFORMATION:

The wire rope used to tow cars has to resist the pull of the wrecker and the car being towed. The action of the two cars or forces, which is equal and in opposite directions, causes the wire rope to get longer. This condition is known as tension.

MATERIALS:

Tension apparatus, steel and copper wire.

PROCEDURE:

1. Set up apparatus with the steel wire.
2. Indicator should be at zero.
3. Turn crank one revolution. Observe weight on indicator.
4. Continue turning handle until wire breaks.
5. Record weight.
6. Follow same procedure using copper wire.

TENSION

SHOP ____________________ NAME ______________________________

CLASS ____________________ JOB SHEET NO. 12-1

QUESTIONS

1. Which was stronger, the steel or copper wire? Why?

2. Give the weights of the wires' resistance at one turn of the handle.

3. At what force did each of the wires break?

4. If a rod having a cross-sectional area of 2 square inches is supporting a load of 100,000 lbs., what is the tension?

5. A suspended fixture weighs 60 lbs. The load is equally distributed through four ½-inch-diameter rods. What is the tension on each rod?

SIMPLE STRESS

COMPRESSION

Strength of Materials – Machinists – Unit XII Job Sheet No. 2

OBJECTIVE:

To learn when an object is under compression.

WANTED:

Conclusions as to when an object is under compression.

RELATED INFORMATION:

You are sitting on a chair. Each leg of a chair used to support you as a person sitting on it pushes against the floor. Each leg resists the action of the floor and the weight of your body. This tendency to shorten a piece of material is known as compression.

Compression can be solved by the unit stress formula:

$$R = \frac{F}{A}$$

MATERIALS:

¼" steel rod, ¼" brass rod, compression machine.

PROCEDURE: (Demonstration by instructor)

1. Set up apparatus with steel rod as material.
2. Apply compressive force to material.
3. Note amount of effort to compress steel rod.
4. Set up brass rod in the same manner as step 1.
5. Apply compressive force to brass rod.
6. Note amount of force required.
7. Does it take more pressure to compress the brass or the steel?

COMPRESSION

SHOP ____________________ NAME ________________________________

CLASS____________________ JOB SHEET NO. 12-2

PROBLEMS

1. A piece of brass having a cross-sectional area of 3 square inches is compressed by a force of 45,000 lbs. What is the unit stress in compression?

2. Check the compressive force by mathematical computation of the steel rod used in the experiment.

3. A building weighs 200 tons. The weight is equally distributed on twenty 9-inch x 9-inch posts. What is the compressive force of each of the posts?

SIMPLE STRESS

SHEAR

Strength of Materials - Machinists – Unit XII Job Sheet No. 3

OBJECTIVE:

To learn what is meant by shear and how to solve to overcome it.

WANTED:

Explanation of shear and method of solving it.

RELATED INFORMATION:

When a body fails (breaks down) because of excessive shearing stress, a sliding of the particles in one plane past the particles in an adjacent plane (see Fig. 1) has taken place.

The area that is sliding or tends to slide is the area stressed in shear.

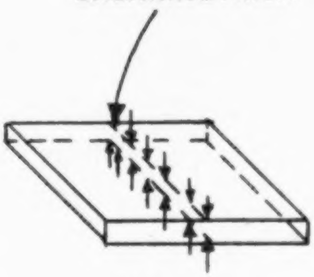


FIG. 1

Shear is given in psi, or pounds per square inch. The formula for finding shear is:

$$\text{Shear (s)} = \frac{\text{Force (F)}}{\text{Cross-Sectional Area (A)}}$$

EXAMPLE:

To find the shear for a sheet of carbon steel having a force of 84,000 lbs. over an area of 2 square inches.

Substituting in the formula $s = \frac{F}{A} = \frac{84{,}000}{2}$

the shear will be 42,000 lbs. per square inch.

TOOLS AND MATERIALS:

Shears, pieces of copper, aluminum, and sheet metal of approximately the same thicknesses.

PROCEDURE: (Demonstration by instructor)

Cut each of the pieces of metal. Which seems easiest to cut with the shears? Do you think if the pieces were thicker, it would have been more or less difficult to cut them? Record your results.

SHEAR

SHOP ____________________ NAME ____________________________________

CLASS ____________________ JOB SHEET NO. 12-3

QUESTIONS

1. Which material seemed to be the easiest to cut with the shears? Why?

2. If the shearing force was 56,000 lbs./square inch for the sheet metal used in the experiment, what force was required to cut it?
   (Hint: F = s x A. Find A by measuring width and thickness of piece).

3. Find shearing force for the copper sheet if the shear for copper is 20,000 psi.

4. What is the force required to cut the aluminum if the shear for the metal is 12,000 psi?

5. Find the cross-sectional area of a sheet of steel metal needing a force of 85,000 lbs. to cut it.

SIMPLE STRESS

BENDING AND TWISTING

Strength of Materials – Machinists – Unit XII Job Sheet No. 4

OBJECTIVE:

To learn what is meant by bending and twisting in a shaft and how to overcome it.

WANTED:

Method of controlling bending and twisting.

RELATED INFORMATION:

When a shaft is suspended by bearings, care must be taken that the space between the bearings is not so great that the shaft will bend.

At the same time the shaft is turning, a twisting force (torsion) is being applied to the shaft.

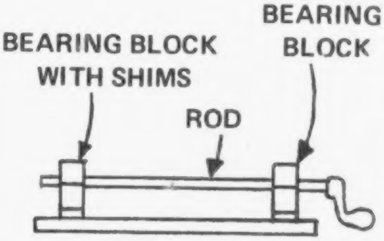


FIG. A

TOOLS AND MATERIALS:

Torsion-testing apparatus as shown in Fig. A.

PROCEDURE:

1. Move bearings to their maximum distance. Measure distance from wood base to bottom of rod at each of the bearing blocks and in the center of the apparatus. Record your results.

2. Rapidly turn handle of crank connected to the rod. Do you notice any whip in the rod? How can this action, if it occurs, be overcome?

3. Remove shims from bearing without crank handle. Tighten bearing cap so rod is secure. Try turning handle. What happens? Would the same thing happen on a shaft if one of the bearings was too tight?

BENDING AND TWISTING

SHOP ____________________ NAME ____________________________________

CLASS ____________________

JOB SHEET NO.12-4

QUESTIONS

1. What are two machine parts in the shop that depend upon correct bearing loads for their operation:
    a.
    b.
2. How can twisting be overcome?
3. What is torsion?
4. Why were shims used in the bearing?
5. Can a shorter distance between bearing surfaces help to keep a shaft aligned?

SIMPLE STRESS

ULTIMATE STRENGTH AND ELASTIC LIMIT

Strength of Materials – Machinists – Unit XII Job Sheet No. 5

OBJECTIVE:

To learn what is meant by ultimate strength and elastic limit and how they are used.

WANTED:

Explanation of how elastic limit and ultimate strength differ.

RELATED INFORMATION:

Elastic limit is the maximum stress which a material will take before becoming deformed.

Ultimate strength is the maximum unit stress which the material can withstand just before breaking.

Ultimate strength is expressed in pounds per square inch (psi). In tension, the ultimate strength is called the ultimate tensile strength; in compression, the ultimate compressive strength; in shear, the ultimate shearing strength.

You can see that a knowledge of the ultimate strength of a material will let you produce parts without chances of any part failing.

Look at the tables on average strength data in the Machinery's Handbook They are in the section on Strength of Materials.

The formula for finding ultimate strength is:

$$\text{Ultimate Strength (St)} = \frac{\text{Force (F)}}{\text{Cross-Sectional Area (A)}}$$

TOOLS AND MATERIALS:

Tension apparatus; steel, brass, copper and aluminum wire.

PROCEDURE:

1. Set up tension apparatus with steel wire. (Be sure wire is straight and does not have any bends in it.)
2. Turn crank handle one-half revolution. Record force.

3. Release tension on handle and see if it returns to its original position.

4. Continue this procedure of one-half-revolved turns until you have reached elastic limit of the wire. Record force.

5. Turn crank handle until wire breaks. Record force.

6. Follow same procedure to find elastic limit and ultimate strength of the other wires.

ULTIMATE STRENGTH AND ELASTIC LIMIT

SHOP ____________________ NAME ______________________________

CLASS ____________________ JOB SHEET NO. 12-5

PROBLEMS

1. Find the ultimate compressive strengths of the following materials:
    a. Steel Casting
    b. Granite
    c. Structural Steel

2. Find the ultimate tensile strengths of the following materials:
    a. Wrought iron
    b. Brass Wire
    c. Portland Concrete

3. Find the ultimate shearing strengths of the following:
    a. Rivet Steel
    b. Machinery Steel

4. A ¼" diameter steel guy wire is used to hold a pole steady. What will be the ultimate strength if the force necessary to break it is 2450 lbs?

    $$\left(St = \frac{F}{A} = \frac{F}{r^2 \times \pi}\right)$$

5. A $\frac{3}{4}$ - inch diameter steel rod broke under a tensile load of 20,000 lbs. What was its ultimate strength?

SIMPLE STRESS

FACTOR OF SAFETY

Strength of Materials – Machinists – Unit XII Information Sheet No. 2

OBJECTIVE:

To learn what is meant by the factor of safety and how to use it.

RELATED INFORMATION:

The draftsman, machinist, or carpenter in using various parts of a machine or structure must have a knowledge of how stresses which do not exceed certain limits are computed.

Knowing these limits, a working margin of safety against failure of the machine or structure can be assumed.

The factor of safety is the ratio of the ultimate strength of the material to the allowable working stress. The formula follows:

$$\text{Factor of Safety (X)} = \frac{\text{Ultimate Strength (St)}}{\text{Allowable Working Stress (W)}}$$

Several conditions affect the proper allowable working stress and factor of safety. They are:

1. Material
2. Allowable working stress does not exceed elastic limit.
3. Chances of overloading
4. How load is applied

Look up the general factors of safety in the Machinery's Handbook.

FACTOR OF SAFETY

SHOP ____________________ NAME ____________________________________

CLASS ____________________ INFORMATION SHEET NO. 12-2

PROBLEMS

1. What is the factor of safety of a steel structure having an ultimate strength of 60,000 psi and an allowable working stress of 15,000 psi?

2. What is the factor of safety of a cast-iron base having an ultimate strength of 90,000 psi and an allowable working stress of 4500 psi?

3. What is the allowable working stress of a timber structure with an ultimate strength of 8,000 psi and a factor of safety of 8?

4. A hydraulic steel jack with a 2-inch-diameter steel piston raised a load of 50,000 lbs. The ultimate strength of this steel is 48,000 psi. What is the factor of safety?

5. The cast-iron legs of a machine have a square cross-section. Each leg supports a load of 15,000 lbs. If a factor of safety of 6 is used, what is the size of each leg?

Ask your instructor for Achievement Test No. 12 after you have completed this unit's work.

BEARINGS

FRICTION

Strength of Materials – Machinists – Unit XIII Information Sheet No. 1

OBJECTIVE:

To learn what is meant by friction as applied to machines.

RELATED INFORMATION:

With the increased exphasis being placed on faster speeds, not only in automobiles, but in machines as well, the need to overcome friction has become a major task. Friction, as you may remember from your physics, is the resistance that a body meets when in contact with a surface on which it moves. If one body slides on another, it is called sliding friction, while when one body is rolling on another, in such a manner that new surfaces are always in contact, it is called rolling friction. An example of rolling friction is the action of an automobile tire and the road,while the movement of the wheel bearing on the axle is considered sliding (axle) friction.

Friction varies greatly between different materials depending upon the action and speed. You learned in physics that surfaces in contact result in a coefficient of friction depending upon the materials involved. For instance, a cast-iron sleeve revolving in a bronze bushing has a coefficient of friction of 0.21. This 0.21 means the revolving force on the sleeve has to have a ratio of $\frac{21}{100}$, before it can move in the bronze bushing. Further, if the revolving force is 2.1 lbs., the frictional resistance it had to overcome was $\frac{2.1}{.21}$, or 10 lbs.

Some of the rules to remember in dealing with friction are:

1. Friction depends upon the quality of the contacting surfaces. (Polished surfaces give less friction than rough ones).
2. Sliding friction is greater than rolling friction.
3. The greatest resistance of friction occurs when a body is put into motion initially.

FRICTION

SHOP ____________________ NAME ______________________________________

CLASS ____________________ INFORMATION SHEET NO. 13-1

QUESTIONS

1. What is friction?

2. Why is friction being considered today more so than in former years?

3. State two types of friction.
    a.
    b.

4. How do they differ?

5. What is meant by the coefficient of friction?

6. Give three principles of friction.

    a.

    b.

    c.

7. Find the coefficient of friction for the following in the Machinery's Handbook.
    a. Bronze on bronze
    b. Bronze on wrought iron, slightly lubricated.
    c. Cast iron on wrought iron, dry

BEARINGS

LUBRICATION

Strength of Materials - Machinists – Unit XIII Job Sheet No. 1

OBJECTIVE:

To learn how lubrication affects friction.

WANTED:

Extent to which lubrication has an effect on friction.

RELATED INFORMATION:

What can be done to reduce friction? This sentence represents an every-day problem in industry throughout the world. The wear on moving parts causes a breakdown in a machine according to the amount of friction. The cam, the connecting rod, etc. are examples of parts that lose effort because of friction.

Oil, grease and coolant are materials used to overcome a certain amount of the effect of friction. Do you go up to your instructor and say, "I burnt a drill"? His first question is, "Did you use a coolant?" Your yes reply means that the speed was so fast the coolant did not overcome the friction. As a result, something had to take the heat, which in this case was the drill. But the drill material,not being able to withstand the heat, failed.

Each oil, grease and coolant has a particular use. Become familiar with these materials if you are to see that the machines you use get good mileage for their price.

TOOLS AND MATERIALS:

Steel plate, heavy steel block, oil.

PROCEDURE:

1. Try pushing the heavy steel block on the dry steel plate. Does the block move easily?

2. Add a few drops of oil to the plate and try pushing the steel block across it. What happens?

LUBRICATION

SHOP ____________________ NAME ____________________________________

CLASS ____________________ JOB SHEET NO. 13-1

QUESTIONS

1. Why are lubricants used on moving parts?

2. Give reasons for a piston's going through the wall of cylinder block.

3. Why was the heavy steel block so much easier to push on the oiled surface?

4. Give examples where lubrication is necessary on machines in the shop.

5. Can lubrication always take care of friction? Why?

BEARINGS

TYPES

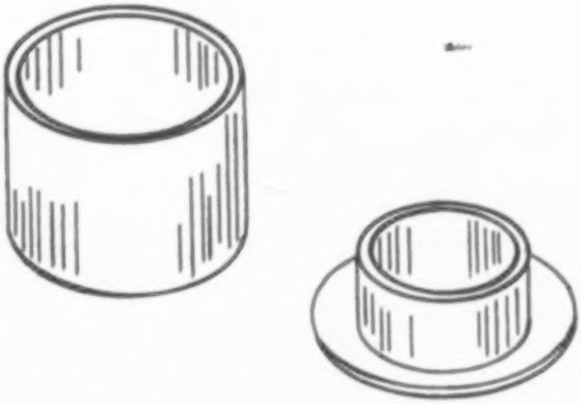
Strength of Materials – Machinists – Unit XII Information Sheet No. 2

OBJECTIVE:

To learn how to identify the various types of bearings.

RELATED INFORMATION:

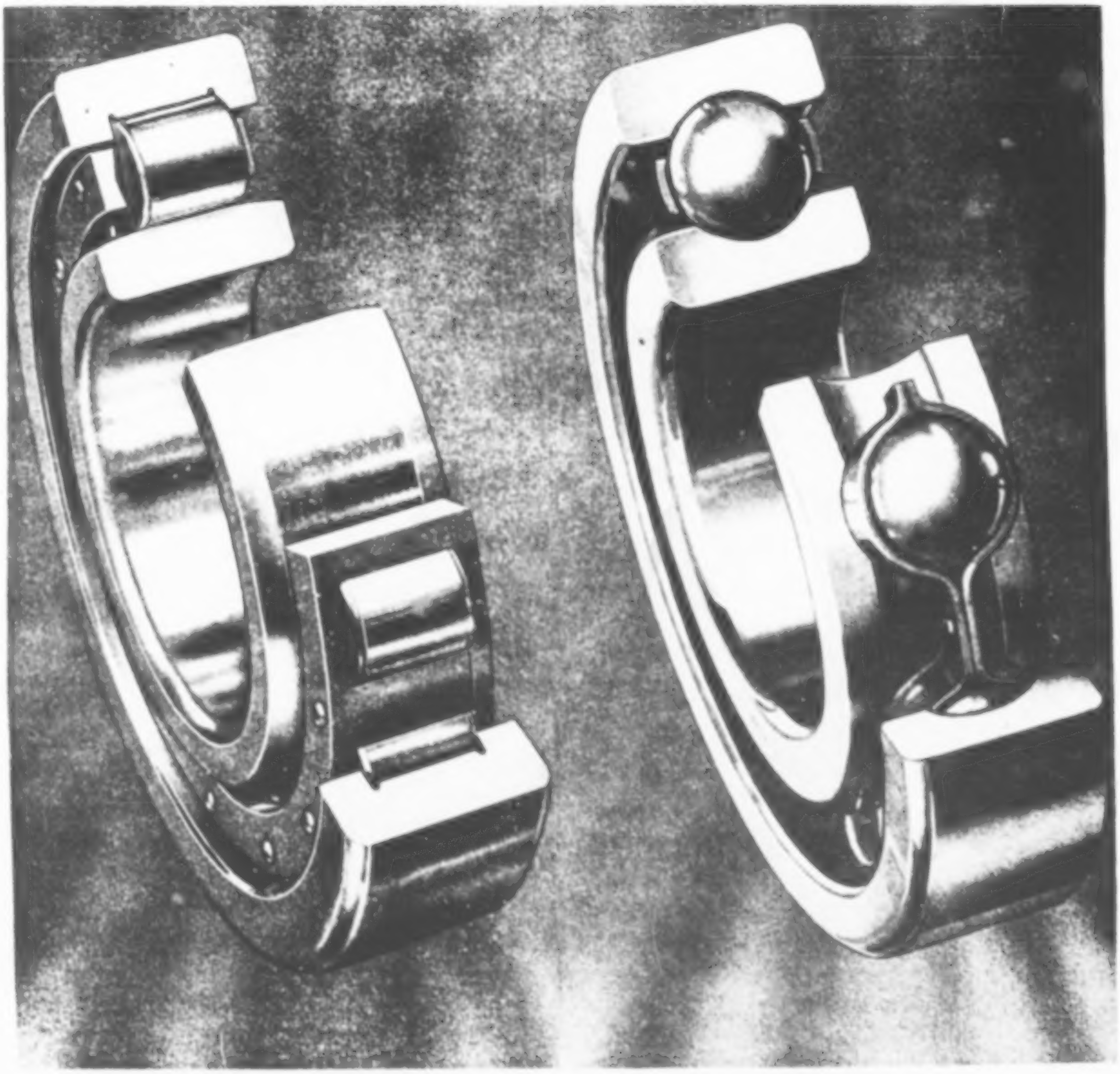
You learned that friction is produced by two materials that are in rubbing contact with each other. You also discovered that friction can be reduced to a certain extent by proper lubrication. In the plain type of bearing (Fig. 1) this reasoning holds true.



PLAIN AND FLANGED BEARINGS
FIG. 1

For certain slower shaft speeds, this type of bearing will give a satisfactory performance. But if a machine has to be run at a high speed, mechanical means in the form of roller or ball bearings (Fig. 2) must be used with lubrication to cut down on the friction.

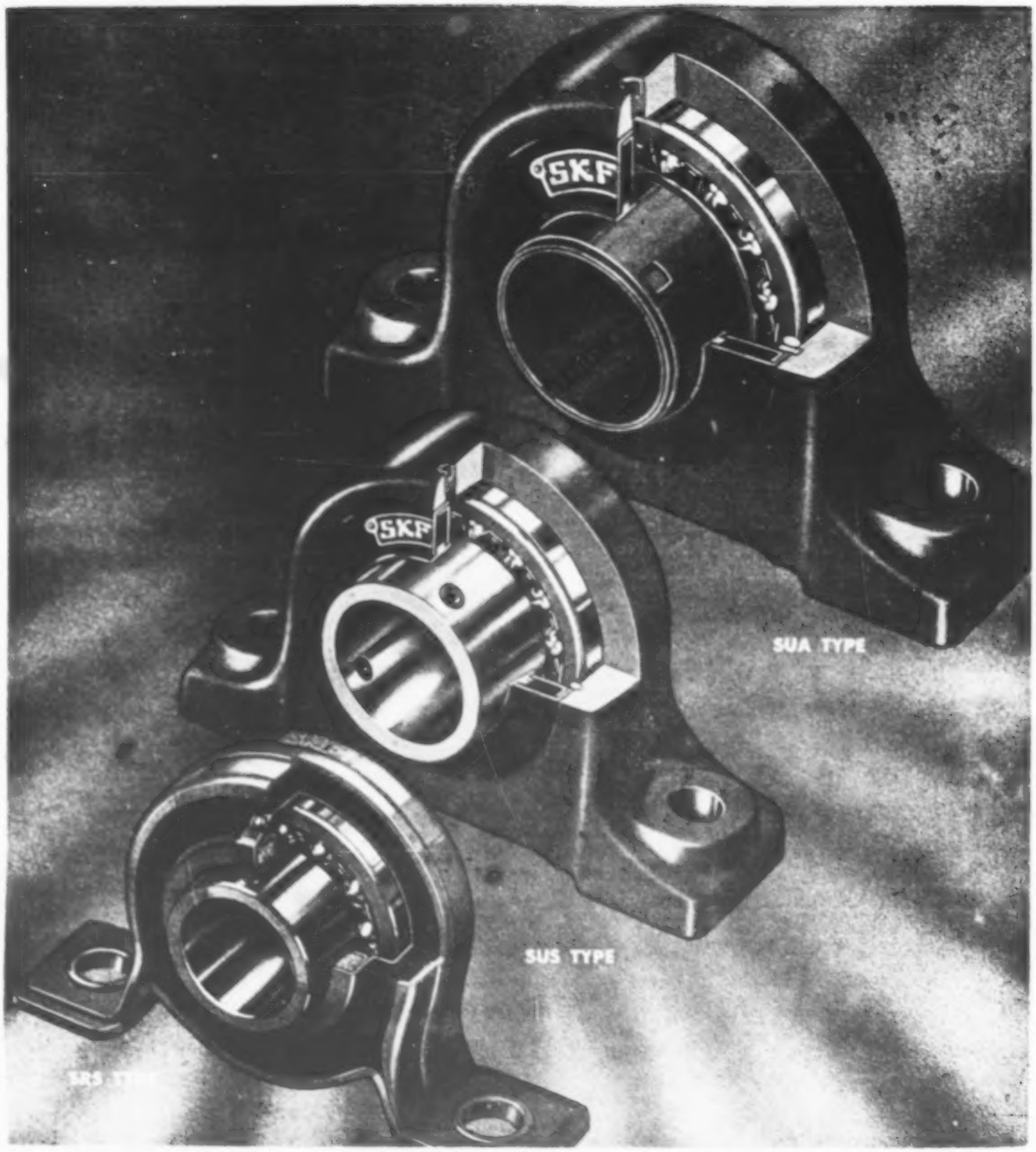
If you remember that the principle function of a bearing is to prevent the failure of moving parts, you will save yourself many headaches. A poorly lubricated bearing or a machine being run at too high a speed is a common cause of bearing failure.



CYLINDRICAL
ROLLER BEARINGS

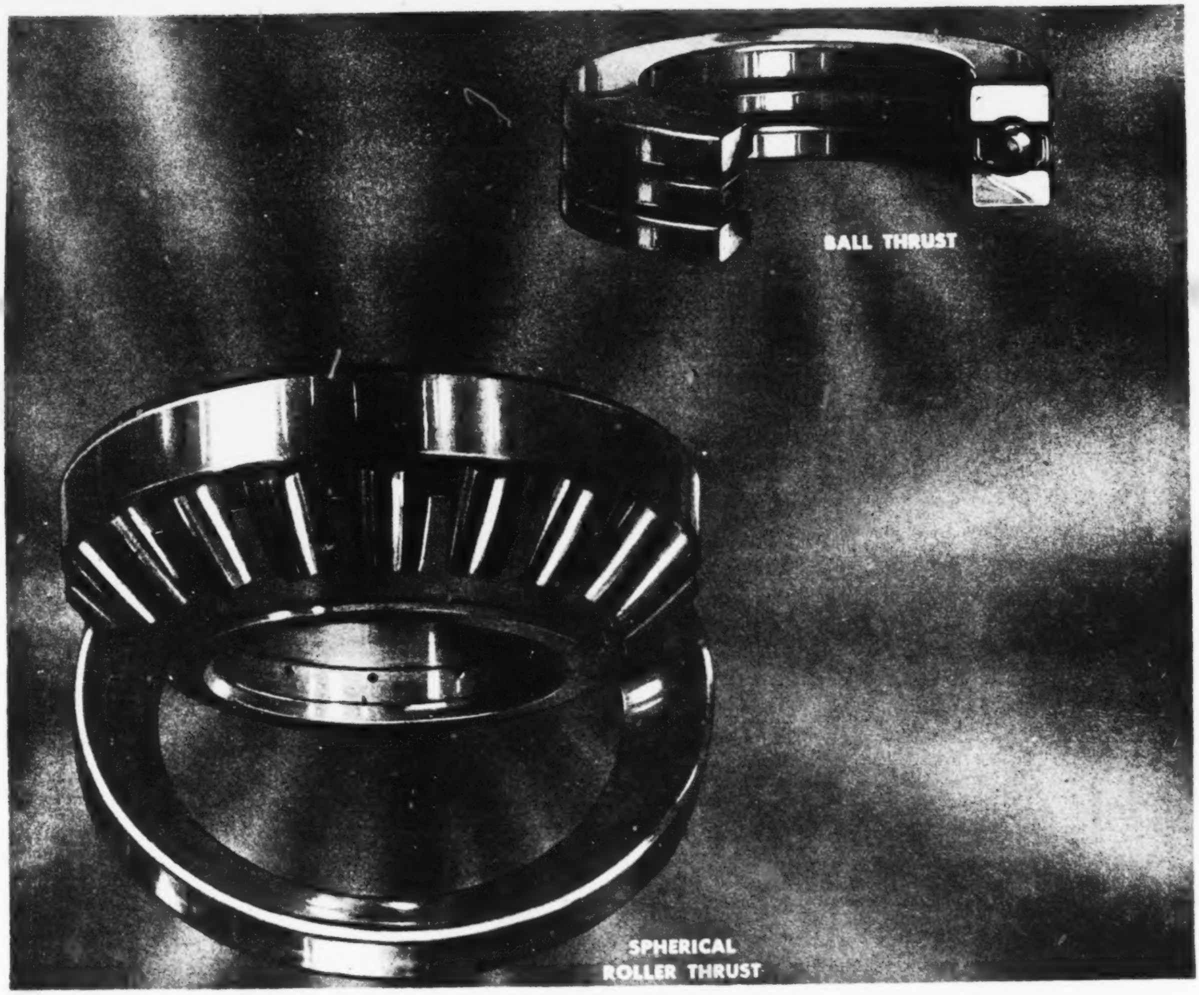
SINGLE ROW, DEEP GROOVE
BALL BEARINGS

FIG. 2


SKF
SKF
SUA TYPE
SUS TYPE
SRS TYPE

SRS, SUS AND SUA TYPE BALL BEARING UNIT PILLOW BLOCKS

FIG. 3



BALL AND SPHERICAL ROLLER
THRUST BEARINGS

FIG. 4

If a shaft is rotating without a tendency to shift with a force in other than its circular motion, a journal bearing (Fig. 3) will serve the purpose. If you look at the machines in the shop, you will find the higher speed shafts have longer bearings than the slower moving ones.

When the shaft load is a combination of parallel and perpendicular forces, a thrust bearing (Fig. 4) is used. This style of bearing eliminates the threat of the shaft's moving out of place, or it takes care of thrust motions, such as the action of an axle and wheel on an automobile which has radial motion while moving down the street in a straight line but has a thrust action added when the car goes around a corner.

3

TYPES

SHOP ____________________ NAME ______________________________ _____

CLASS ____________________ INFORMATION SHEET NO. 13-2

QUESTIONS

1. Name three types of bearings.
   a.
   b.
   c.

2. What style of bearing is used where a shaft runs with forces perpendicular to the bearing surfaces?

3. What style of bearing is used when forces parallel to the motion of the shaft are introduced?

4. Give the name of a machine used in the shop for each type of bearing.

5. Investigate with your instructor several machines having bearings to see if you can find causes for possible bearing failure. (For example, you may find a worn shaft or a loose shaft in a bearing).

Ask your instructor for Achievement Test No. 13 after you have completed this unit's work.

FASTENERS

SCREW THREADS

Strength of Materials – Machinists – Unit XIV   Job Sheet No. 1

OBJECTIVE:

To learn the use of screws in industrial practice.

WANTED:

Identification and uses of various threads.

RELATED INFORMATION:

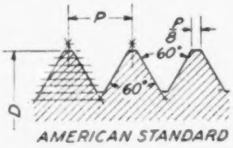
In the industrial field, where drawings and blueprints are used, screw threads are important in design. The process of fastening parts together is either one with the idea of permanent application, like the rivet, or taking apart for repair or adjustment, like the screw.

As a mechanic, you should be familiar with the common types of threads and fastenings and their use. In drafting practice, you will learn the proper method of showing them on a drawing.

The principal uses of threads are:

1. Fasteners
2. Adjustment
3. Transmission of power

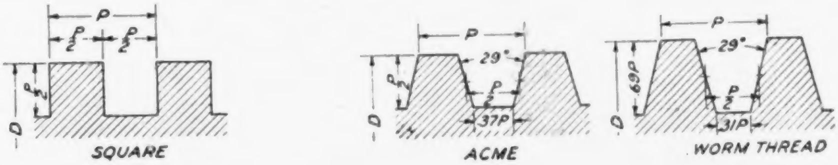
The *American Standard Thread* (see Fig. 1) with flattened crests and roots is used in the United States to a great extent. These threads are used on screws, bolts, and nuts for fastening and adjustment purposes.



AMERICAN STANDARD

FIG. 1

The Square, Acme, and Brown and Sharpe worm threads (see Fig. 2) are used for the transmission of power and motion.



SQUARE

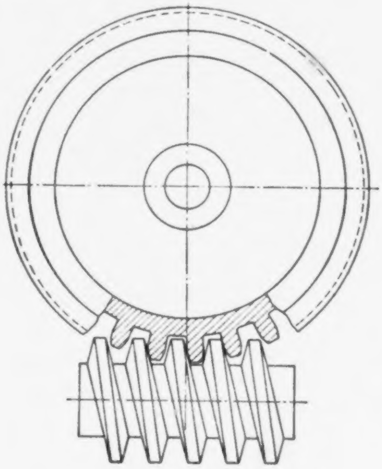
ACME

WORM THREAD

FIG. 2

The *square* thread passes on its power parallel to the axis of the thread. A modified form of the square thread is the *Acme*, which is stronger and easier to cut. It finds use where quick disengaging is necessary, such as the lead screws on lathes.

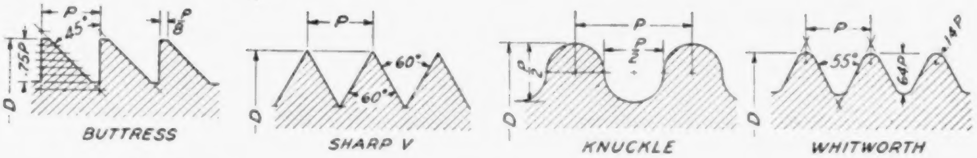
Transmission of power to a worm wheel by a worm (see Fig. 3) gives the 29° worm thread practical use. This thread resembles the acme,as can be seen in Fig. 2. The exceptions are in the depth of thread and width of the flat at top and bottom. Multiple threaded worms may have thread angles up to 60 degrees.



Worm and Wheel

FIG. 3

Some of the other threads that find use in manufacturing processes are shown in Fig. 4.

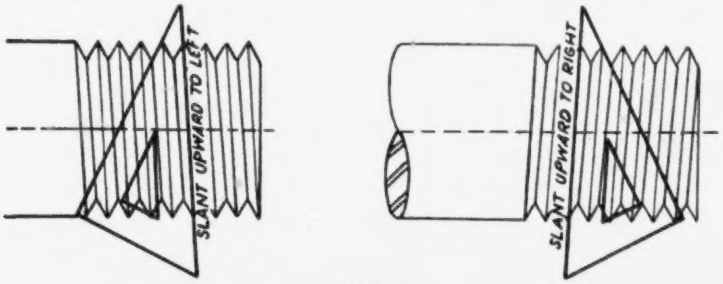


BUTTRESS SHARP V KNUCKLE WHITWORTH

FIG. 4

The *knuckle* thread, which is cast or rolled, is used on incandescent lamps, plugs, etc. The *Whitworth* finds great use in England, being applied in the United States in some design work. The *buttress* thread is used to resist the recoil on guns. Notice the design of the thread whereby it can take pressure in one direction.

On specifying the hand of threads, usually the right-hand is understood to be called for. If left-hand threads are required (where direction of rotation may cause the screw or bolt to loosen, as is the case of the wheel on an automobile), they are noted at the end of the thread specification. For example, a right-hand, ½" diameter, 13 thread per inch, National Coarse thread would be listed as follows: ½-13N.C., while the same thread in a left-hand would be specified: ½-13NC. – L.H. The hands of a thread can be identified as shown by Fig. 5.



RIGHT-HAND **FIG. 5** LEFT-HAND

When a quick advance of the screw or bolt is required, as on valves, fountain pens, etc., two or more threads are cut side by side. (Have instructor show and explain pitch and lead on single, double, and triple threads).

TOOLS AND MATERIALS:

Steel rule, outside calipers, thread gage, right-and left-handed varieties of the following threads:
American Standard, square, Acme, buttress, knuckle, Whitworth, and Brown and Sharpe.

PROCEDURE:

1. Identify each of the screw threads. Record.

2. Taking the straight edge as shown in Fig. 5, identify the hand of the various threads. Record next to type of thread.

3. Using outside calipers and steel rule, find diameters or size of thread. Record alongside name of thread.

4. Using thread gage, find number of threads per inch. Record in proper place.

5. Set up column listing threads as they would be specified on drawing. Example: ¾ – 10 NC, or ½-6 square

SCREW THREADS

SHOP ____________________ NAME ____________________________________

CLASS ____________________ JOB SHEET NO. 14-1

QUESTIONS

1. When is a rivet used to fasten parts together?

2. When is a screw used to fasten parts together?

3. Give three uses of threads.
    a.
    b.
    c.

4. Name several types of threads and their uses.

5. What does L.H. after a thread specification indicate?

FASTENERS

NUTS, SCREWS AND BOLTS – STRENGTH REQUIREMENTS

Strength of Materials – Machinists – Unit XIV Job Sheet No. 2

OBJECTIVE:

To learn the strength requirements of the various screw thread applications.

WANTED:

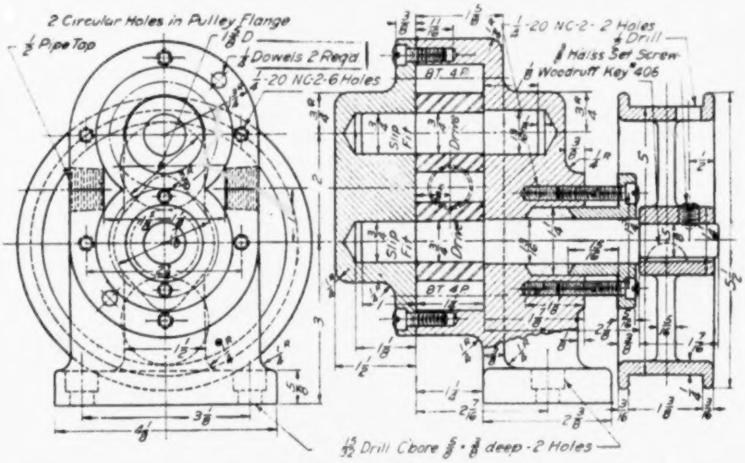
Ways of using screw threads properly.

RELATED INFORMATION:

The required screw thread is an important part of the machinist's work. Using too large a size material may not be bad when you figure the part will not fail or break. But from the design angle, too much material is just as bad as too little. Today, with economy, the by-word of manufacturing processes, knowledge of proper limits of the strength of various materials and forms of materials is necessary for proper and good design.

On machines where frequent removal and putting back of fastening materials is necessary, bolts are usually used. Studs are preferred where thread wear is great because they can be removed when not of further use. Tap bolts, with larger heads than cap screws, find use under certain conditions.

If two or more bolts are used to hold two parts that have a tendency to cause a shearing action on the bolts, the bolts should be helped by dowel pins. (See Fig. 1)


2 Circular Holes in Pulley Flange
1/2 Pipe Tap
1 5/8 D
1/8 Dowels 2 Reqd
1/4-20 NC-2-6 Holes
1/4-20 NC-2-2 Holes
1/4 Drill
3/8 Hallss Set Screw
1/8 Woodruff Key #406
BT 4P
Slip Fit
Drive
15/32 Drill C'bore 5/8 · 3/8 deep -2 Holes
3 1/8
4 1/8
2 7/16
2 3/8
1 3/8
5 1/2

Lubricant pump

FIG. 1

Vertical bolts that have a tendency to loosen, due to vibration or other causes, should be placed with their heads up.

A combination of nut and jam nut or two jam nuts is used as a locking device (see Fig. 2).

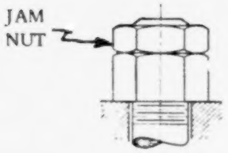


FIG. 2

To prevent a nut or bolt head from sticking over the edge of a corner, the tapped or drilled hole should be located, at least at a radius of half the distance across corners of the bolt head or nut.

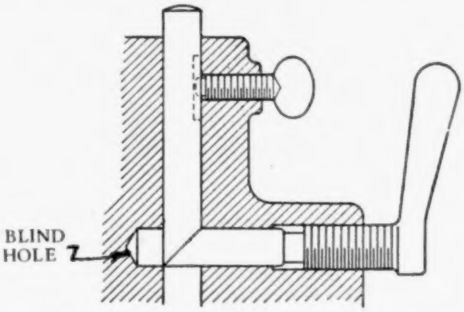


FIG. 3

Blind holes (see Fig. 3) are used where the danger of gas leakage or rusting out is present. The holes should not be tapped into the space having gas vapor or liquid pressures.

Proper spacing should be allowed to fit wrenches to nuts or bolt heads. This practice allows proper tightening and loosening of the fastening devices.

Screws or bolts should be placed or spaced to give the best possible load action. (see Fig. 4)

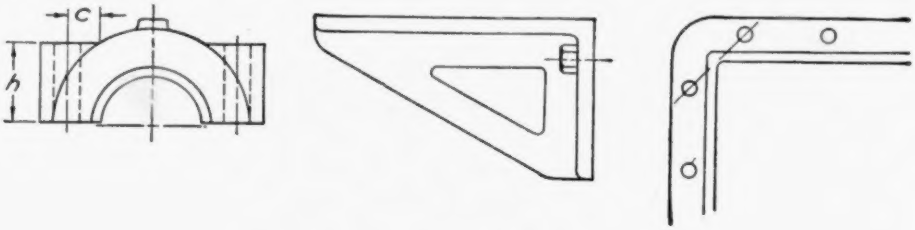


FIG. 4

The sizes and kinds of screws, bolts, and nuts should be kept to a minimum on a design to avoid the use of an unnecessary number of wrenches.

TOOLS AND MATERIALS:

Bracket, lag screw, two plates with bolt holes and dowel pins, jam nuts and bolts, wrenches, split bearing, weights.

PROCEDURE:

1. Mount bracket on wall with lag screw in lower hole of bracket.
2. Hang weights on end of bracket until you notice the upper edge pulling away from the wall. Record weight.
3. Remove screw and fasten bracket in top hole.
4. Hang weights on end until you have reached about one and one half times the weight recorded in step one. What do you notice? Explain the reason for this happening.
5. Bolt plates lightly together, placing oil or grease on the facing sides. See what happens when the top surface is pushed in one direction while the bottom plate is held in a vise. Be sure dowel pins have been removed.
6. Take plates apart and insert dowel pins. Close plates and fasten together with bolts. See what happens when you try to move the top surface in one direction while the bottom plate is held in the vise. Record results.
7. Tighten block with one nut. See if you can loosen it with a wrench.
8. Tighten block with two jam nuts. See if you can loosen lower nut. Explain your results.
9. Put shaft in loosened bearing.
10. Tighten until shaft moves freely. If the spacing between the bolt holes was greater, what would happen to the bearing cap if it was tightened too much?

NUTS, SCREWS AND BOLTS

SHOP ____________________ NAME ________________________________

CLASS ____________________

JOB SHEET NO. 14-2

QUESTIONS

1. Why is using the correct screw thread size important to the machinist?

2. How can bolts be held more securely and thus prevent a shearing action upon them?

3. Why is a jam nut used?

4. What are blind holes?

5. How should screws or bolts be placed?

6. Why should sizes and kinds of screws, bolts and nuts be kept to a minimum?

7. Why does the upper bolt hold better than just the lower one in the experiment?

FASTENERS

NUTS, SCREWS AND BOLTS – THREADED LENGTH

Strength of Materials – Machinists – Unit XIV Information Sheet No. 1

OBJECTIVE:

To learn the required length of threaded parts and materials used in their construction.

RELATED INFORMATION:

The thread length of a bolt or screw should be able to stand a shearing force equal to the tension force at the root of the thread. In other words, the threads should not break if the threaded part of a bolt or screw is long enough.

The following rules can safely be followed when specifying the length of bolts or screws and thicknesses of nuts.

CONDITION	FORMULA
Steel bolt and nut	Nut Thickness = $\frac{\text{Thread Dia.}}{3}$
Steel bolt and cast-iron nut	Nut Thickness = $\frac{\text{Thread Dia.}}{2}$
Wrought-iron and steel nuts	Nut Thickness = $\frac{7}{8}$ Thread Dia.
Wrought-iron and steel bolts having cast-iron nuts	Nut Thickness = $1\frac{5}{16}$ Thd. Dia.
Tapped holes in cast iron used for stud bolts, cap screws, tap bolts	Depth = 1¾ Thd. Dia.
Tapped holes in steel used for stud bolts, cap screws, tap bolts	Depth = 1¼ Thd. Dia.
Length of thread on bolts or screws for use in cast-iron	Length = 1½ Thd. Dia.
Length of thread on bolts or screws for use in steel or wrought-iron	Length = 1 Thd. Dia.

The use of bolts and screws in the many industries has made the manufacturers conscious of the need for a very good product. With the great advances in the science of metals,more and varied uses of fastening products are being found.

Low-alloy, S.A.E. steels are used for bolts where high impact strength, toughness, and resistance to fatigue are required. Heat-treating (operation of heating and cooling metals) is used to increase these properties.

Where better resistance to heat and corrosion is a requirement, stainless steel finds use.

The non-ferrous alloys are used to make nuts, bolts, and screws having all or some of the following characteristics:

1. Heat resistance
2. Corrosion resistance
3. Acid resistance
4. Lightness
5. Low coefficient of expansion

NUTS, SCREWS AND BOLTS

SHOP ____________________ NAME ______________________________

CLASS ____________________ INFORMATION SHEET NO. 14-1

QUESTIONS

1. Give the thickness of a nut that could be safely used to withstand a load from the following thread diameters:
   a. 1"-8 N.C. steel bolt and nut
   b. 1"-8 N. C. wrought-iron bolt and cast iron nut
   c. ½"-20 N. F. steel nut
2. Give the depth of tapped hole or length of thread for the following diameters:
   a. ½"-13 N. C. tapped hole in cast iron
   b. 1¼"-12 N. F. bolt to be used in steel
3. What must the thread length of a bolt withstand?
4. When are low-alloy S.A.E. steels used for bolts?
5. Give some characteristics of non-ferrous alloys used to make nuts, bolts and screws.

FASTENERS

SET SCREWS

Strength of Materials – Machinists – Unit XIV Information Sheet No. 2

OBJECTIVE:

To learn the holding power of set screws.

RELATED INFORMATION:

A set screw is a round piece of bar stock threaded to the head or completely threaded. (see Fig. 1) They are used to prevent any movement between two pieces of material by screwing through one and pressing against the other. (see Fig. 2)

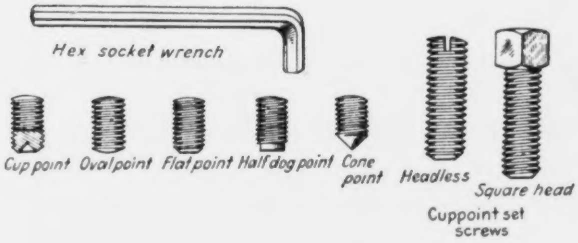
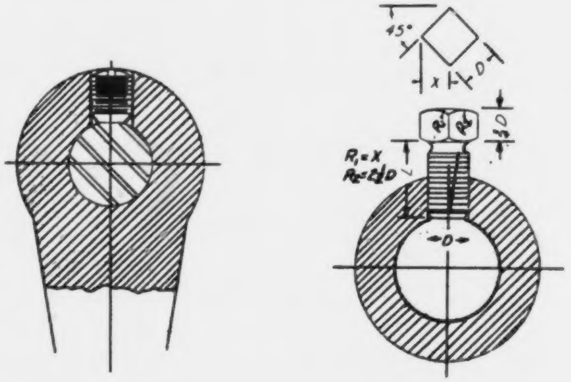

Hex socket wrench
Cup point
Oval point
Flat point
Half dog point
Cone point
Headless
Square head
Cuppoint set screws

FIG. 1



HEADLESS SET SCREW

AMERICAN STD. SET SCREW

FIG. 2

The holding power that a set screw must exert to be of practical use can be found by the following formula;

$$\text{Holding power (P)} = \frac{63{,}000 \times \text{Horsepower (HP)}}{\text{Shaft R.P.M.}}$$

(63,000 is called a constant. A constant is a figure that has been found to be uniform after experimenting regardless of other changes in a formula).

After solving for the holding power, selection of the type of screw equal to the holding power is necessary. The following table gives the ratings of two types of set screws. (The manufacturing company will send you a rating of their screw).

	CUP POINT	ROUND POINT
THD. DIA. (Inches)	FORCE (Inch-Pounds)	FORCE (Inch-Pounds)
¼	50	48
$\frac{5}{16}$	120	100
$\frac{3}{8}$	240	200
$\frac{7}{16}$	410	360
½	670	600
$\frac{9}{16}$	1000	910
$\frac{5}{8}$	1500	1400
¾	3000	2870
$\frac{7}{8}$	5000	4850
1	8100	7900

EXAMPLES:

What diameter of cup-point set-screw should be used to hold a coupling that is going to transmit 3 HP, safely at a shaft speed of 1800 R.P.M. (revolutions per minute)?

$$\text{Holding power (P)} = \frac{63{,}000 \times \text{HP}}{\text{RPM}} = \frac{63{,}000 \times 3}{1800} = 105 \text{ inch-pounds}$$

Looking at the chart, you will find a $\frac{5}{16}$-diameter cup-point set-screw is required.

SET SCREWS

SHOP ____________________ NAME ________________________________

CLASS ____________________ INFORMATION SHEET NO. 14-2

PROBLEM

Solve for the missing specification in the following problems:

PROB	SET SCR. DIA.	TYPE POINT	H.P.	RPM	HOLDING POWER
a		Cup	10	1800	
b		Cup	6	300	
c		Cup	3		1300
d		Cup		750	3000
e		Round	2	1500	
f		Round	8	600	
g.		Round		1250	2500
h.		Round	4		650
i.	¼	Round	5		
j	½	Cup		600	

FASTENERS

EYE BOLTS

Strength of Materials – Machinists – Unit XIV Information Sheet No. 3

OBJECTIVE:

To learn the safe load to be applied to eye bolts.

RELATED INFORMATION:

Eye bolts are used for lifting machines and heavy machine parts. Usually two bolts are screwed or tapped and so located to balance the suspended load. Material used is forged mild ductile steel.

When a collar is used on an eye bolt, it should be screwed so that the surfaces meet.

In Fig. 1, you will see the proper proportions for the design of an eye bolt for the safe-working-load formula that follows:

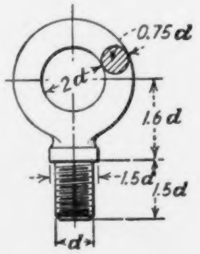


FIG. 1

Safe Load (SL) = 12,000 x Area of Minor Dia.

In other words, if an electric motor weighing 2000 lbs. had to be lifted by two eye bolts, you could solve by the formula and see if the eye bolts you specified could hoist the motor safely.

EXAMPLE:

Two eye bolts each have to carry 1000 lbs. If a ½" dia. eye bolt is specified, you could check thusly:

Find minor dia. area ½" thread in Machinery's Handbook = 0.125

Safe load = 12000 x 0.125 = 1500 lbs.

The bolts will safely carry the motor, since the total load that the bolts can safely carry is 3000 lbs.

EYE BOLTS

SHOP ____________________ NAME ____________________________________

CLASS ____________________ INFORMATION SHEET NO. 14-3

QUESTIONS

1. Why are eye bolts used?

2. If an eye bolt has a collar, what is necessary to give the eye bolt its maximum holding power?

3. Make a sketch of an eye bolt for a ½" diameter thread. Dimension completely.

4. Can two eye bolts having $\frac{5}{8}$ threaded diameters carry a load of 2000 lbs. safely? Show your work as proof.

5. What is the safe load of four ½" threaded diameter eye bolts?

FASTENERS

RIVETS

Strength of Materials - Machinists – Unit XIV Information Sheet No. 4

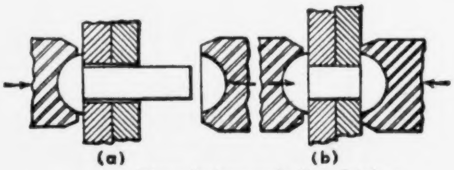
OBJECTIVE:

To learn the size of rivet to specify for minimum strength.

RELATED INFORMATION:

Fastenings are needed where parts of a machine or structure need to be held fast. If a piece does not require mooring or removal, rivets can be used to make a permanent fastening. They are used to hold together the plates of a tank or boiler, a bridge structure, etc.

A wrought iron or steel rivet is heated, pushed through the holes in the connecting parts, and another head is formed. The new head is formed by riveting machines (see Fig. 1).



Rivet before and after driving.

FIG. 1

The diameter of a rivet is proportioned to the plate thickness. The table below lists the required size rivets for lapped joints.

RIVET DIAMETER OF LAPPED JOINTS

Plate Thickness (Inches)	$\frac{1}{4}$ to $\frac{9}{32}$	$\frac{5}{16}$ to $\frac{11}{32}$	$\frac{3}{8}$ to $\frac{13}{32}$	$\frac{7}{16}$ to $\frac{1}{2}$	$\frac{17}{32}$ to $\frac{5}{8}$	$\frac{11}{16}$ to $\frac{3}{4}$	$\frac{13}{16}$ to $\frac{7}{8}$
Rivet Diameter (Inches)	$\frac{5}{8}$	$\frac{11}{16}$	$\frac{3}{4}$	$\frac{7}{8}$	1	$1\frac{1}{8}$	$1\frac{1}{4}$

RIVETS

SHOP ____________________ NAME ________________________________

CLASS ____________________ INFORMATION SHEET NO. 14-4

PROBLEMS

Specify the proper size rivet for the following plate thicknesses:

a. $\frac{13}{32}$

b. $\frac{9}{16}$

c. $\frac{1}{4}$

d. $\frac{9}{32}$

e. $\frac{11}{16}$

f. $\frac{7}{8}$

g. $\frac{1}{2}$

h. $\frac{11}{32}$

i. $\frac{5}{8}$

j. $\frac{19}{32}$

FASTENERS

KEYS

OBJECTIVE:

To learn how to find the length and size of a key having equal strength to the shaft.

RELATED INFORMATION:

A key is a steel fastening extending into two machine parts to prevent movement between them (see Fig. 1).

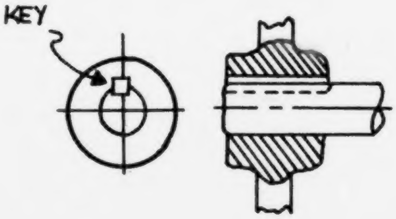


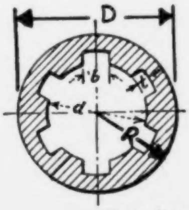
FIG. 1

The formula for finding the length of a key is as follows:

Square Key Length (KL) = 1.6 x Shaft Dia. (Dia.)

The various sizes of keys are given in the Machinery's Handbook according to shaft sizes. Have your instructor show you how to locate the key sizes.

Where large forces are going to be applied to a shaft, such as an automobile transmission, a spline is used instead of a key. Splines may be four, six, ten, etc.



—Six-spline hub.

FIG. 2

KEYS

SHOP ____________________ NAME ____________________________________

CLASS ____________________ INFORMATION SHEET NO. 14-5

PROBLEMS

1. Solve for key lengths and sizes:
    a. 1" shaft requires square key

    b. 1½" shaft requires square key

2. What shaft diameter would a ¼" square key be used on?

3. Why are keys used on machine parts?

4. What is the shaft diameter for a $\frac{1}{8}''$ x $\frac{3}{32}''$ flat key?

5. How deep does a ½" key-way go into a shaft?

FASTENERS

TAPERS

Strength of Materials – Machinists – Unit XIV   Information Sheet No. 6

OBJECTIVE:

To learn how tapered shanks firmly seat and center themselves in spindles.

RELATED INFORMATION:

A variety of types of tools and machine parts (twist drills, end mills, lathe centers, etc.) have shanks that taper to fit into spindles or sockets on a machine. This arrangement allows for an accurate centering of the tool in the spindle and offers a fairly firm grip for the tool that has to revolve or remain stationary.

There are several standard types of tapers used. The Morse and Brown and Sharpe styles are the standard ones most commonly used by American manufacturers of machines.

Morse tapers are used on a variety of tools and have exclusive use on the shanks of twist drills.

Brown and Sharpe tapers find their greatest use on arbors, collets, and milling machine tool spindles.

Other tapers that find usage on machines are the Jarno and the American Standard.

A taper pin, on the other hand, is used as a means of fastening a part to a shaft when the load is not too great. They make the mating parts turn as one.

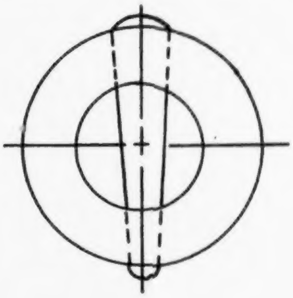


FIG. 1

TAPERS

SHOP ____________________ NAME ________________________________

CLASS ____________________ INFORMATION SHEET NO. 14-6

QUESTIONS

1. What is a taper?

2. Why is a taper used?

3. Name several types of tapers.

4. Which two are mostly used?
    a.
    b.

5. Give an exclusive machine area for each type.

6. Why are taper pins used?

Ask your instructor for Achievement Test No. 14 after completing this unit's work.

SHAPING AND FORMING METALS

HOT WORKING

OBJECTIVE:

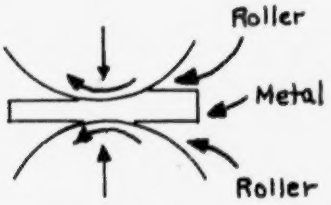
To learn how metals are shaped by hot-working.

RELATED INFORMATION:

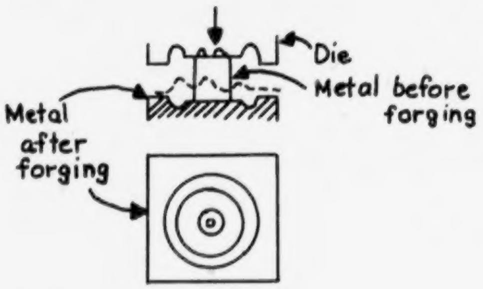
Casting, as you have learned, is a basic way of forming metals. The special kind of casting made by pouring molten steel into a cast-iron mold is called an *ingot*. This ingot is the shape of the metal before shaping and forming.

A metal in a powder state can be formed by pressing it in a metal form. The resulting heat from the pressure causes the material to fuse into a solid. Small parts, gears, etc. make good use of this method.

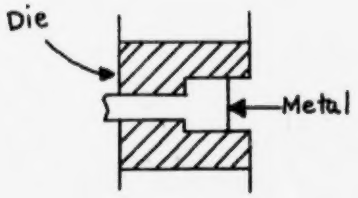
Hot-working of metals is thought of as an operation that mechanically deforms the metal in a temperature range that will not affect the normal grain structure. Some of the common methods used in the hot shaping of metals are rolling, forging, hammering, and extrusion.


Roller
Metal
Roller

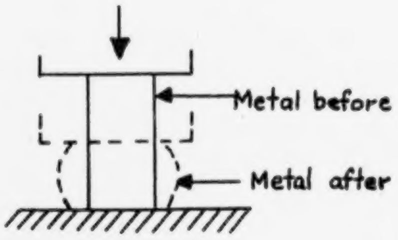
ROLLING


Die
Metal before forging
Metal after forging

DIE FORGING



EXTRUSION


Metal before
Metal after

HAMMERING

Rolling and forging get the steel into the required shape and improve its mechanical properties. Where simple shapes are to be made in large quantities, rolling is the cheaper process of the two. Sheets, structural shapes, rails, etc. are made by passing the heated material between two rolls revolving in opposite directions. The rolls have a space between them somewhat less than the height of the piece entering them. The rolls grip the metal and deliver it in a reduced and slightly formed shape to the next set of rollers. This process is continued until the required shape is formed.

Forging or hammering is the simplest method of reducing metal to the desired shape by deforming it. The steam hammer is the principal type of hammer used for hot forging, although the advance in hydraulic presses may have an effect on this method. The forging done by the hammer method is of the blacksmith variety. When drop-forging is used, a piece of metal about the size of the required shape is placed between die faces and drawn together. The die resembles the finished part. Automotive parts of steel and brass, naval gun barrels, oil-distilling apparatus, tool steel and wrought-iron parts are usually made through forging.

Some metals can be formed by pressing through an opening. Brass, lead and its alloys are formed by this method,called extrusion. The advantages of this method are perfectly round rods or rods of varied shapes. The metal to be extruded is placed in a closed chamber fitted with an opening at one end and a piston at the other end. The metal is forced out of the opening by hydraulic pressure, forming the desired shape through the use of a die.

HOT WORKING

SHOP ____________________ NAME ___________________________________

CLASS ____________________ INFORMATION SHEET NO. 15-1

QUESTIONS

1. What is the basic form for the greatest percentage of metals?
2. Why is there an exception?
3. What is the simplest method of shaping metal?
4. Explain what is meant by drop forging.
5. What is extrusion and why is it used?
6. Give the name of the casting before it is shaped and formed.
7. What is hot working?
8. What do rolling and forging do to steel?
9. Which is the cheaper process, rolling or forging?
10. Explain the operation of rolling.

SHAPING AND FORMING METALS

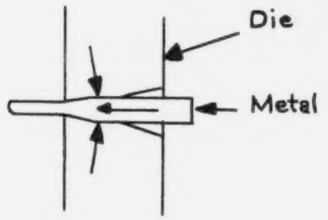
COLD WORKING

OBJECTIVE:

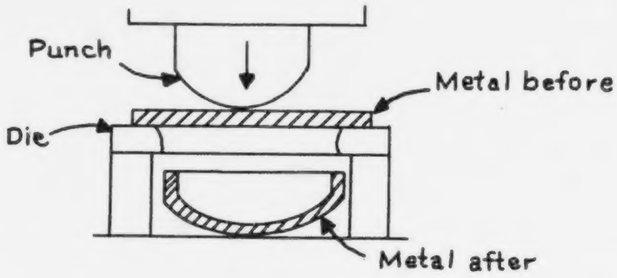
To learn how metals are cold-worked.

RELATED INFORMATION:

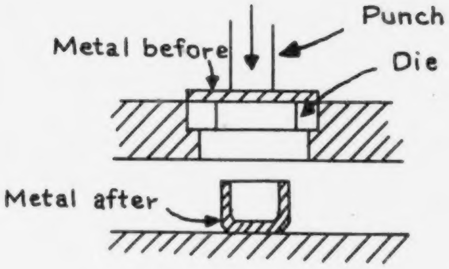
The discovery of metals was the birth of working metals at ordinary temperatures. Cold-working of metals was an art practiced by the ancients. Today, modern practices have given us cold-rolling, pressed metals, and drawing, to name a few.



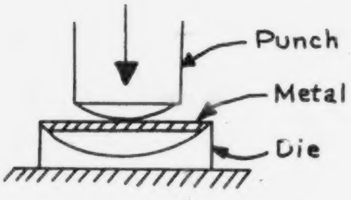
WIRE DRAWING


Punch
Metal before
Die
Metal after

CUPPING


Punch
Metal before
Die
Metal after

DEEP DRAWING


Punch
Metal
Die

STAMPING

Cold-rolling produces a finish for hot-rolled metals. The bright, smooth surface of cold-rolled steel, for example, insures accurate dimensioning and increased tensile strength. Cold-rolling is used to produce sheets, strip steel, and bar stock, following a process similar to hot-rolling. The difference may be that the cold-rolled metal may have to be annealed after several passes through the rollers to keep it in a workable condition.

Metal in the form of cold-rolled or hot-rolled sheets or strips may be formed into various shapes in metal dies. Through the use of proper die design, pressing of the metal may consist of many operations, some of which are bending, shearing, blanking, punching, flanging, embossing, etc. Flat stock of steel, brass, copper, aluminum, or other metal is placed between the dies of a slow-action press which forces the metal to assume the desired shape. The modern automobile and airplane, household appliances, workshop tools, are some of the products produced in this fashion.

Drawing is the operation of reducing the thickness of a material while increasing its length or size. Many shapes of tubes, bars, wire, and sheets are produced by this process. Kitchen utensils, such as pots and pans, would cost too much if drawing was not used.

In any of the cold-working processes, it must be remembered that the metals can only be deformed to a certain point, otherwise cracking is likely to result. You must realize that a metal, like an elastic band, has a certain point to which it can be stretched without breaking, otherwise you will not be able to specify the correct metal for a part.

COLD WORKING

SHOP ____________________ NAME ____________________________________

CLASS ____________________ INFORMATION SHEET NO. 15-2

QUESTIONS

1. When was cold-working discovered?

2. Give the cold-working process for the following parts:
    a. Household appliances
    b. Strip steel
    c. Wire
    d. Bar stock

3. Name a few modern practices used in cold-working.

4. What precaution must be taken in the cold-rolling of metals? Explain.

Ask your instructor for Achievement Test No. 15 after completing this unit's work.

WELDING

DEFINITIONS

Strength of Materials – Machinists – Unit XVI Information Sheet No. 1

OBJECTIVE:

To learn the various types of welds and how they are defined.

RELATED INFORMATION:

Welding is one of the most important ways of putting together metal parts. This method is used when casting costs are too high or where design calls for lighter weight than can be achieved by casting. Through the welding process, the complicated automobile structure is attained, as well as the many forms of machinery, buildings, and aircraft and shipbuilding industries.

Welding of metals may be done in three ways depending upon the heating materials and metals being used. The methods are pressure, fusion, and casting.

Pressure welding consists of heating the parts to be joined to a plastic or near melting stage. The parts are pressed together at a contact pressure that squeezes out any impurities and results in good union of the parts. Today most pressure welds are made by heating the parts by electricity. The current heats most rapidly at the contact between the parts, where the resistance is the highest. Pressure is applied to the plastic surfaces and they are squeezed together to remove oxide and slag to form a firm bond. This method is applied to both butt and lap welding in the production of pipe out of sheet by rolling the sheet into a cylinder and welding the long seam. Fabrication of automobile bodies, metal furniture, refrigerators are some of the many other uses of pressure welding.

Fusion welding is a joining process in which the union of the parts is obtained by actual fusion of metal along the contacting surfaces of the mating parts. The heat necessary for fusion welding may be supplied by oxyacetylene flame, by an electric arc between metallic or carbon rods and by any process following the above forms. This type of welding finds a variety of uses in the various machine and structural industries.

Thermit welding can be considered the casting-process method, where molten iron is run into a mold built around the parts at the point at which they are to be connected. The liquid metal used consists of finely divided iron oxide and aluminum, which is lighted in a crucible. The reaction gives the welded members a liquid metal that forms a firm union of the parts on cooling.

DEFINITIONS

SHOP ____________________ NAME ______________________________

CLASS ____________________ INFORMATION SHEET NO. 16-1

QUESTIONS

1. Name the three types of welds.
    a.
    b.
    c.

2. When is welding used?

3. Explain the three types of welds and give a use for each.

4. Which method do you think is being used by industry? Why?

5. Do you think welding will replace the casting process? Why?

WELDING

OXYACETYLENE

Strength of Materials – Machinists – Unit XVI | Job Sheet No. 1

OBJECTIVE:

To learn how to weld with the oxyacetylene torch and the various joints that can be used.

WANTED:

Explanation of how metals are welded by oxyacetylene.

RELATED INFORMATION:

Many different metals can be welded with the oxyacetylene torch.

The intense heat required for welding metal by gas process is obtained by lighting a mixture of oxygen and acetylene, or oxygen and hydrogen.

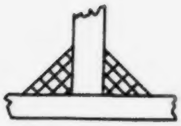
TOOLS AND MATERIALS:

Welding equipment, welding rods, and the following metals:
Cast iron, steel, and angle iron.

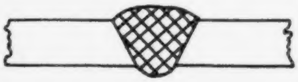
PROCEDURE: (To be done in machine shop by instructor)

1. Explain use of welding equipment:
    - a. Torch
    - b. Gas and Gages
    - c. Hood
    - d. Torch tip size
    - e. Welding rods
    - f. Welding safety

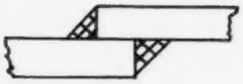
2. Using pieces of steel, prepare and weld them in the following ways:
    - a. Lap joint
    - b. Butt joint
    - c. Fillet weld
    - d. Bead
    - e. "V" groove



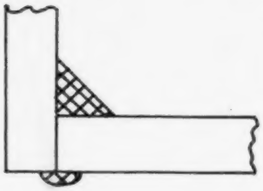
FILLET WELD



BUTT JOINT WITH V GROOVE



LAP JOINT



CORNER JOINT WITH FILLET AND BEAD WELDS

3. Show necessary steps in welding cast iron and limitations.

4. Demonstrate various methods of welding angle iron.

5. Students should record notes and ask any questions to make welding of metals clear in their minds.

OXYACETYLENE

SHOP ____________________ NAME ____________________________________

CLASS ____________________ JOB SHEET NO. 16-1

QUESTIONS

1. What is oxyacetylene?

2. Name some of the safety precautions to follow when using this type of equipment.

3. Make sketches showing the following welds:
    a. Lap joint

    b. Butt joint

    c. Fillet weld

4. State the gas mixture used in the oxyacetylene process.

5. What is the advantage of gas welding in field work?

WELDING

ARC

Strength of Materials – Machinists – Unit XVI

Job Sheet No. 2

OBJECTIVE:

To learn what is meant by arc welding and how it is used.

WANTED:

Explanation of how arc welding is used.

RELATED INFORMATION:

An electric arc is a continuous spark between two terminals. The tremendous heat at the point of welding melts a small pool of metal in the work. Additional metal is obtained from the electrode or filler rod.

All steels are weldable under proper conditions. To obtain high welding speeds, it is necessary to go deeply into the plates being welded.

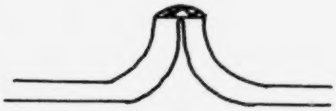
TOOLS AND MATERIALS:

Arc welding equipment, pieces of steel.

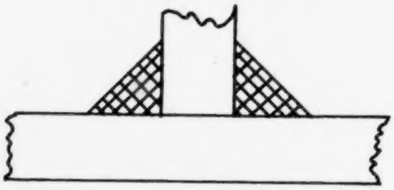
PROCEDURE: (To be done in the machine shop)

1. Explain use of arc welding equipment.

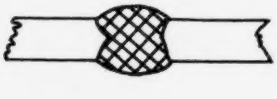
2. Make the following welded joints:
   a. Corner c. Tee
   b. Edge d. Double butt



EDGE JOINT



TEE JOINT WITH FILLET WELDS



DOUBLE BUTT

ARC

SHOP ____________________ NAME ____________________________________

CLASS ____________________ JOB SHEET NO. 16-2

QUESTIONS

1. What is arc welding?

2. Name some of the safety precautions in using this type of equipment.

3. Make sketches of the following welds:
    a. Corner

    b. Double butt

    c. Tee Joint

4. What type of voltage is needed to operate arc welding equipment?

5. Does the arc welding set-up require a greater or lesser amount of money to install and operate than gas welding?

Ask your instructor for Achievement Test No. 16 after completing this unit's work.

MECHANICAL TESTING OF METALS

TESTING LABORATORY

Strength of Materials – Machinists – Unit XVII   Information Sheet No. 1

OBJECTIVE:

To learn how metals are mechanically tested.

RELATED INFORMATION:

The purpose of testing laboratories is to determine the strength and properties of materials. The results insure quality and economy in manufacture and performance in use on machines or structures for the materials tested.

Testing machines may vary, but they are designed to determine the mechanical properties of materials. Some tests commonly used are tension, compression, torsion, flexure, hardness, endurance to repeated stresses,and impact tests. Special tests may include resistance to weather, light exposure, paper folding, vibration, etc.

ASSIGNMENT:

Your instructor will plan a field trip to a testing laboratory in order to acquaint you with the mechanical testing of materials.

GLOSSARY

alloy	–	metal made by fusion of two or more metals.
annealing	–	putting steel into shape for easy machining.
arc weld	–	joining metals by use of an electrical arc.
bead	–	method of laying down a weld.
bearing stress	–	force of rivet or bolt against the plate.
bearing surface	–	plate area in front of a rivet or bolt needed to resist a shearing reaction.
bending strength	–	ability of an object to resist bending under a load.
blow molding	–	method of forming used with thermoplastic materials.
butt joint	–	method of placing two pieces of material together end to end.
butt weld	–	type of weld used to fasten a butt joint.
calendering	–	process of making thermoplastic into film and sheeting.
case-harden	–	method of hardening the surface of a metal.
casting	–	method of molding a part by shaping a solid mass of metal from a liquid state.
casting plastics	–	process of shaping plastics by molding a fluid mass.
coating	–	method of applying plastic to metal, wood, paper, fabric, leather, glass, etc.
compression	–	squeezing together of fibers.
compression molding	–	process of squeezing of a plastic material into a desired shape by applying heat and pressure.
critical range	–	1292° for steel.
cross-sectional area	–	amount of material an object has at right angles to an axis and measured in squared terms.

crystal state	–	size and shape pattern of carbon-steel particles.
cyaniding	–	surface hardening of small parts made from low carbon steel.
deflection	–	downward bending.
deform	–	to change the shape of a body.
destructive test	–	failure of welded joint outside the weld.
dielectric strength	–	ability of an object to resist the passage of electricity.
electric insulator	–	a substance that will not conduct electricity.
electrode	–	terminal of an electric source.
extrusion	–	forcing out at the surface.
extrusion molding	–	method of forming thermoplastic materials into sheet, tubes, rods, etc.
fabricate	–	to construct by putting together.
factor of ignorance	–	ratio used to take care of unknown load conditions.
factor of safety	–	ratio of safe load to the maximum applied load.
fiber stress	–	ability of structural shape to resist strain.
field weld	–	work not done in shop.
fillet	–	rounded surface to break a sharp corner.
filler	–	material used to give plastics added strength.
filler rod	–	rod used in arc welding to add metal to joint.
fillet weld	–	triangular weld.
fixture	–	method used to hold an object in place.
flammable	–	able to burn.
flexible	–	not rigid.

flexure	–	ability to bend.
forging	–	forming a shape by heating and hammering.
forming	–	shaping.
fracture of metals	–	breaking a piece of metal to show the texture.
fulcrum	–	about which a lever turns.
fusion welding	–	process of joining metal parts in the molten state without applying mechanical pressure.
gas cutting	–	dividing a material by means of a chemical behavior of oxygen.
grain structure	–	crystal-like formation of metals.
hardness	–	amount of resistance of a metal to penetration.
heat-treatment	–	method of treating metals.
high-pressure laminating	–	method of shaping thermosetting plastics by use of high heat and pressure.
hood	–	covering used to protect face from welding heat, light and metal splattering.
hot-working	–	metal shaped when hot.
hydraulic	–	method of offering resistance when a quantity of a liquid is forced through a small opening.
ingot	–	a mold in which hot metal is cast.
injection molding	–	method of forcing fluid plastic at high pressure through a nozzle into a cold mold.
intricate	–	difficult to understand; complicated.
lap joint	–	two objects laid out in such a manner that one extends over the other.
lever	–	a rigid piece capable of turning around a point known as a fulcrum.
lineal measure	–	distance along a line.

load – a weight resting upon something.

mill scale – particles left on metals after shaping in steel mills.

modulus of elasticity – ratio of unit stress to unit strain.

nitriding – surface hardening of special alloy steels.

non-ferrous – any metal lacking iron or steel.

normal grain structure – required crystal patterns of metal.

normalizing – improving grain structure of otherwise poor steel.

oxyacetylene – mixture of oxygen and acetylene.

pearlite structures – cooling a steel so that the structure contains 0.85% carbon.

physical properties – nature characteristics which identify materials.

plastic nature – capable of being deformed continuously without rupture.

plumb – vertical or true.

point of zero shear – section where the bending moment is the greatest.

precipitation hardening – process of hardening by heat treatment.

pressure weld – process of welding metals in a fluid state by aid of mechanical pressure.

projection weld – localizing the heat in joining overlapped parts.

reaction – body force opposed to a weight or load.

reinforcing plastics – molding impregnated reinforced material under low pressure.

resistance butt weld – pressure welding of butt joint.

resistance welding – pressure welding process wherein the welding heat is obtained by passing an electric current between the contact areas.

resultant – equal in effect to two or more forces.

root – zone at bottom of cross-sectional space provided to contain a fusion weld.

seam weld – linear resistance welding process.

shear – action tending to divide a body.

shock strength – ability of a body to resist a blow.

shrinkage – the amount a material decreases.

specification – statement containing details of construction.

sprig – small headless nail or brad.

spot weld – fastening of materials at various points to hold it in place.

stiffener – used to keep an object from bending.

stress – subject to action of an external force.

tempering – making hardened steel suitable for a cutting tool.

tension – act of stretching.

thermoplastic – softens when exposed to heat, hardens on cooling.

thermosetting plastic – permanent setting plastics.

translucent – admitting diffused light causing objects beyond to be hard to distinguish.

transparent – admitting light so that objects can be seen beyond it.

uniformly distributed load – weight evenly placed over the entire beam.

web – vertical section of structural member.

FORMULAS

$$\text{Unit Stress} = \text{Resistance (R)} = \frac{\text{Total force (F)}}{\text{Cross-sectional Area (A)}}$$

$$\text{Unit Strain} = \text{Deformation (D)} = \frac{\text{Total Strain (S)}}{\text{Length of Body (L)}}$$

$$\text{Shear (s)} = \frac{\text{Force (F)}}{\text{Cross-sectional Area (A)}}$$

$$\text{Ultimate Strength (St)} = \frac{\text{Force (F)}}{\text{Cross-sectional Area (A)}}$$

$$\text{Factor of Safety (X)} = \frac{\text{Ultimate Strength (St)}}{\text{Allowable Working Stress (W)}}$$

$$\text{Holding Power (P)} = \frac{63{,}000 \times \text{Horsepower (HP)}}{\text{Shaft R.P.M.}}$$

Eye Bolt Safe Load (SL) = 12,000 x Area of Minor Dia. of Thread

Square Key Length (KL) = 1.6 x Shaft Dia. (Dia.)

ABBREVIATIONS

R_1 = first resultant

R_2 = second resultant

F_1 = first force

F_2 = second force

F_3 = third force

π = pi (3.1416)

in.^{2} = square inches

= lb. (s)

ft. = foot

″ = inches

psi = pounds per square inch

A = area

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INDUSTRIAL MATERIALS

Strength of Materials – Machinists – Unit I
Achievement Test No. 1

OBJECTIVE:

To see if you can recognize the various industrial materials.

TOOLS AND MATERIALS:

Pieces of cast iron, steel, aluminum, lead, copper, brass.

ASSIGNMENT:

Identify by name the various pieces of metal.

a.

b.

c.

d.

e.

f.

QUESTIONS:

1. Name the two groups of abrasives

   a.

   b.

2. Tell how the two types of plastic are classified and explain the difference between them.

3. What is the chemical symbol for iron?

4. Give some uses of steel.

5. Name five non-ferrous metals.

STUDENT'S NAME____________________________

THE PRODUCTION OF IRON AND STEEL

Strength of Materials – Machinists – Unit II   Achievement Test No. 2

OBJECTIVE:

To see if you understand how iron and steel are produced.

QUESTIONS:

1. Match the process and resulting product.

   a. Blast furnace ______ u. high-grade tool steel
   b. Aston-Byers ______ v. high carbon steel
   c. Bessemer ______ w. low-carbon steel
   d. Open-hearth ______ x. wrought iron
   e. Crucible ______ y. fine-quality steel
   f. Electric ______ z. pig iron

2. Name several uses for wrought iron.
   a.
   b.
   c.

3. State three physical characteristics of Bessemer steel.
   a.
   b.
   c.

4. Name several uses for open-hearth steel.
   a.
   b.
   c.

5. Give the composition of the crucible furnace charge.
   a.
   b.
   c.

6. Give two uses for electric process steel.
   a.
   b.

STUDENT'S NAME______________________________

PRODUCTION OF NON-FERROUS METALS

Strength of Materials – Machinists – Unit III

Achievement Test No. 3

OBJECTIVE:

To see if you have learned how non-ferrous metals are produced.

QUESTIONS:

1. Match the metal with the process used in the production of the metal.

________ a. Bayer
________ b. Smelting and refining
________ c. Electrolysis of natural salts
________ d. Electrothermal distillation
________ e. Orford
________ f. Thermit
________ g. Electrolytic methods

(1) – Copper
(2) – Zinc
(3) – Cadmium
(4) – Nickel
(5) – Magnesium
(6) – Aluminum
(7) – Antimony
(8) – Chromium
(9) – Tin

2. Match the metal with its use:

________ a. Aluminum
________ b. Copper
________ c. Lead
________ d. Zinc
________ e. Tin
________ f. Cadmium
________ g. Magnesium
________ h. Nickel
________ i. Mercury
________ j. Tungsten
________ k. Silver
________ l. Chromium
________ m. Molybdenum

(1) – Tank linings
(2) – Galvanizing material
(3) – Flashlight work
(4) – Chemical vats
(5) – In high-tensile steel
(6) – Coins
(7) – Filaments
(8) – Cast or wrought shapes
(9) – Part of low-melting alloy
(10) – In spring steel
(11) – Plating of hardware
(12) – Plating on containers
(13) – In laboratory apparatus
(14) – Electrical wiring
(15) – Hand tools

STUDENT'S NAME________________________

GENERAL PHYSICAL PROPERTIES

Strength of Materials – Machinists – Unit IV Achievement Test No. 4

OBJECTIVE:

To see if you know the general physical properties of industrial materials.

QUESTIONS:

1. Why are metals of greater use than any of the other industrial materials?

   a.

   b.

   c.

   d.

   e.

   f.

   g.

2. Name two light-weight metals that can be used in various ways.
   a.
   b.

3. How can steel be made soft or hard?

4. Find densities of the following in a handbook:
   a. Cast iron
   b. Lead
   c. Brass
   d. Aluminum
   e. Mild steel

5. Name five general physical properties of industrial materials.

   a.

   b.

   c.

   d.

   e.

STUDENT'S NAME______________________________

MECHANICAL PROPERTIES OF MATERIALS

Strength of Materials – Machinists – Unit V　　　Achievement Test No. 5

OBJECTIVE:

To see if you know the meaning of the various mechanical properties of materials.

PROBLEMS: A. Match column (A) with column (B) for each of the following:

		(A)	(B)
_____	1.	Ductility	a. – Ease with which a material can be hammered into any desired shape.
_____	2.	Elastic limit	b. – The ability to resist rupture when greatly extended in tension.
_____	3.	Stiffness	c. – Property of a material whereby it can support a large load without losing its shape.
_____	4.	Hardness	d. – Ability of a material to store energy and resist impact.
_____	5.	Malleability	e. – When a material has been so deformed that it will not return to its original shape.
_____	6.	Impact strength	f. – The toughness of a body to take the work-energy of a blow or falling weight.
_____	7.	Resilience	g. – Resistance of a substance to the separation of its particles by a penetrating action.

B. Using the formula for Modulus of Elasticity

$E = \frac{F \text{ x } L}{A \text{ x } s}$, solve the following:

1. A 1-square inch steel bar, 60 inches long has a weight of 10,000 lbs. suspended at the lower end which causes the bar to stretch 0.02 inches. What is the modulus of elasticity?

2. A 29-ft. long structural steel bar having a cross-sectional area of 3 square inches and elasticity of 29,000,000 lbs. per square inch has a weight of 10,000 lbs. attached to it. How many inches does it stretch?

C. Give a chemical test for the following metals:

1. Magnesium
2. Monel
3. Stainless steel
4. Tin
5. Steel

STUDENT'S NAME______________________

THE PLAIN CARBON STEELS

Strength of Materials – Machinists – Unit VI
Achievement Test No. 6

OBJECTIVE:

To see if you have learned the construction and uses of plain carbon steels.

QUESTIONS:

1. What do all steels contain?

2. The effect of the carbon in the steel depends upon:
   a.
   b.
   c.

3. How are steels classified? Why?

4. Give the approximate composition of the following steels:
   a. C1010
   b. 1041
   c. C1006

5. Match the following:

_________ a. 1006
_________ b. 1015
_________ c. 1025
_________ d. 1035
_________ e. 1045
_________ f. 1065
_________ g. 1085
_________ h. 1095

1. connecting rods
2. cold chisels
3. files
4. screws
5. springs
6. screw drivers
7. levers
8. razors
9. crankshafts
10. chain

STUDENT'S NAME_________________________

THE CONTROL OF PHYSICAL PROPERTIES OF METALS

Strength of Materials – Machinists – Unit VII — Achievement Test No. 7

OBJECTIVE:

To see if you have learned how to control the physical properties of metals.

QUESTIONS:

1. Explain what is meant by the heat treatment of steel.

2. The effect of the carbon in the steel depends on:
    a.
    b.
    c.

3. Name several reasons for warping and cracking.

4. Why is a hard case given to steel?

5. What is the main purpose of annealing?

6. Explain the term normalizing.

7. Why is nitriding used?

8. What is cyaniding?

9. How can properties of non-ferrous metals be altered to meet exacting requirements of various applications?

10. Match the coated metal with its use.

COATED METAL

______ a. Tin plate
______ b. Zinc galvanizing
______ c. Parkerizing
______ d. Bonderizing
______ e. Surface oxidation

USE

u. gun parts
v. sheet metal work
w. building up of work parts
x. canning industry
y. surface hardening of steel
z. resisting wear on pistons

STUDENT'S NAME______________________________

THE ALLOY STEELS

Strength of Materials – Machinists – UnitVIII Achievement Test No. 8

OBJECTIVE:

To see if you know the reasons why steel alloys are being used in production of objects.

QUESTIONS:

1. What is an alloy steel?

2. Give two examples of elements that combine with steel to form an alloy.
   a.
   b.

3. Give the approximate combination for the following steels:
   a. 5150
   b. 3115
   c. 1340
   d. E3310
   e. C1010

4. State a use for each of the following steel alloys:
   a. 2340
   b. 9260
   c. 4140
   d. 6150
   e. 4340

5. Can you identify the color code for the following:
   a. SAE 1010
   b. SAE 3115
   c. SAE 4140
   d. SAE 5195
   e. SAE 6125

6. What are two possible effects of alloying?
   a.
   b.

7. How is corrosion-resistance taken care of by alloying steel?

8. What does red hardness mean?

9. Which element alloyed with steel shows the greatest effect in the making of a harder product?

10. Why is a protective coating put on iron?

STUDENT'S NAME____________________________

THE PRODUCTION OF CASTINGS

Strength of Materials – Machinists – Unit IX   Achievement Test No. 9

OBJECTIVE:

To see if you know how castings are produced.

QUESTIONS:

1. What is meant by casting?
2. Give examples of parts that may be cast.
3. Name the various types of castings.
4. In what kind of furnace is the metal for the following cast parts melted?
    a. Cast-steel machine housing
    b. Bronze worm-wheel blank
    c. Cast-iron engine block
5. What is a pattern? What is the most commonly used material to make it?
6. How are patterns preserved?
7. Why are metal molds used?
8. Give the advantages and disadvantages of die casting.
9. Why are centrifugal castings made?
10. Name some possible defects of castings.

STUDENT'S NAME________________________

NON-FERROUS ALLOYS

Strength of Materials - Machinists – Unit X Achievement Test No. 10

OBJECTIVE:

To see if you can recognize and know the uses of the various non-ferrous alloys.

PROBLEMS:

Match column (A) with column (B).

______ 1. Commercial Bronze	a. Valve stems
______ 2. Low Brass	b. Flexible hose
______ 3. Duralumin	c. Dye vats
______ 4. Dow Metal	d. Low thermal expansion
______ 5. Monel Metal	e. Screen wire
______ 6. Alnico	f. Easy-melting alloy
______ 7. Solder	g. Bearing metal
______ 8. Babbitt Metal	h. Permanent magnets
______ 9. Invar	i. Screws
______10. Muntz Metal	j. Hammered forgings

STUDENT'S NAME______________________________

THE STRUCTURE OF METALS

Strength of Materials – Machinists – Unit XI Achievement Test No. 11

OBJECTIVE:

To see if you have learned the structure of metals.

QUESTIONS:

1. Name the two characteristics upon which the structure of metal depends.
   a.
   b.
2. What happens when a force exceeding the elastic limit is applied to a metal?
3. If you continued to deform a piece of metal, you would cause it to become:
4. Make a sketch of a body-centered cubic pattern.
5. Sketch the three steps in the growth of a crystal.

STUDENT'S NAME________________________________

SIMPLE STRESSES

Strength of Materials – Machinists – Unit XII

Achievement Test No. 12

OBJECTIVE:

To see if you know simple stresses.

QUESTIONS:

1. Find the unit stress for the following: ($R = \frac{F}{A}$)
   a. A 2-square-inch cross-sectional rod having a load of 100,000 lbs. applied to one end.

   b. A 2 inch x 2 inch steel bar supporting a load of 120,000 lbs.

   c. A 1" diameter steel cable raising a load of 40,000 lbs.

2. Find the unit strain for the following: ($D = \frac{S}{L}$)
   A 30-inch-long wire that stretches 0.0030 inches when a load is applied.

3. State two machine parts in the shop that depend upon correct bearing loads for their operation.
   a.
   b.

4. How can twisting be overcome?

5. What is elastic limit?

6. Explain what is meant by ultimate strength.

7. State the difference between tension and compression.

8. Why is a safety factor used?

9. If a rod has a cross-sectional area of 3 square inches supporting a load of 120,000 lbs., what is the tension in the rod?

10. A machine weighs 2000 lbs. The weight is equally distributed on four legs having a cross-sectional area of 2 square inches. What is the compressive force in each leg?

STUDENT'S NAME ____________________

BEARINGS

Strength of Materials – Machinists – Unit XIII Achievement Test No. 13

OBJECTIVE:

To see if you understand the use of bearings on industrial machines.

QUESTIONS:

1. What is friction?

2. Give three principles of friction.

   a.

   b.

   c.

3. State two types of friction.
   a.
   b.

4. What is meant by the coefficient of friction?

5. Why are lubricants used on moving parts?

6. Can lubrication always take care of friction? Why?

7. Name three types of bearings.
   a.
   b.
   c.

8. Give an example of a machine in your shop for each type of bearing.

STUDENT'S NAME________________________________

FASTENERS

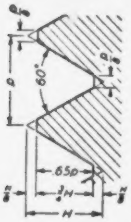
Strength of Materials – Machinists – Unit XIV   Achievement Test No. 14

OBJECTIVE:

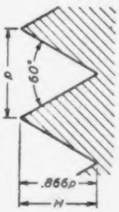
To see if you can specify workable fasteners for certain loads.

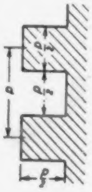
PROBLEMS:

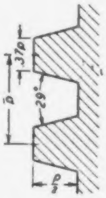
1. Identify the following threads:

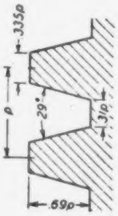


p/8
60°
p
p/8
.65p
H/8
3/4 H
H/8
H

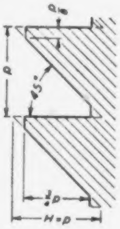








.335p
p
29°
.31p
.69p



p/8
p
45°
3/4 p
H = p

2. Give three uses of threads
   - a.
   - b.
   - c.

3. What does L.H. mean on a thread specification?

4. Why is a jam nut used?

5. What are blind holes?

6. When are low-alloy SAE steels used for bolts?

7. Why are set screws used?

8. Explain the use of eye bolts.

9. When are rivets used in place of screws?

10. When are keys and splines used on a machine?

STUDENT'S NAME____________________________

SHAPING AND FORMING METALS

Strength of Materials – Machinists – Unit XV Achievement Test No. 15

OBJECTIVE:

To see if you can identify the proper methods of shaping or forming metals.

PROBLEMS:

Match the methods in column B with the formed object in column A.

A

_______ 1. Ingot

_______ 2. Rails

_______ 3. Naval gun barrels

_______ 4. Round rods

_______ 5. Strip steel

_______ 6. Workshop tools

_______ 7. Kitchen utensils

_______ 8. Structural shapes

_______ 9. Bar stock

_______ 10. Wire

B

a. Cold-rolling

b. Hot-rolling

c. Casting

d. Pressed metals

e. Drawing

f. Forging

g. Extrusion

STUDENT'S NAME_______________________________

WELDING

Strength of Materials – Machinists – Unit XVI Achievement Test No. 16

OBJECTIVE:

To see if you have learned the various types of welding.

QUESTIONS:

1. State the three types of weld and give a use for each.
    a.
    b.
    c.
2. When is welding used?
3. Explain when the oxyacetylene equipment is used.
4. Make sketches of the following welds:
    a. Lap Joint
    b. Butt Joint
    c. Fillet Weld
    d. Bead
    e. "V" Groove
    f. Corner Joint
    g. Edge Joint
    h. Tee
5. Explain when the arc welding equipment is used.
6. Name some safety precautions when using welding equipment.
7. What must be done to cast iron before it can be welded? Why?
8. How can high welding speeds be obtained?
9. What type of voltage is needed to operate the arc welding equipment?
10. Which method, gas or arc, is more economical to install?

STUDENT'S NAME________________________